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ON THE VARIATIONS OF THE CLIMATE OF THE GEOLOGICAL AND HISTORICAL PAST AND THEIR CAUSES.

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[Read May 16, 1900.]

THIS paper is a revised and enlarged translation of a paper in Swedish, "Om klimatets ändringar i geologisk och historisk tid samt deras orsaker," published in *Ymer* (a journal edited by the Swedish Society for Anthropology and Geology), Stockholm, 1899, p. 353. It is an attempt to apply the results of physical, astronomical, and meteorological research in order to explain the secular changes of climate as recorded by geology and by history. I have in this paper endeavoured to avail myself of the works of eminent physicists, astronomers, and meteorologists, though I have not always accepted their results unaltered. For owing to the intricacy of the problems it may happen that a solution, mathematically and physically correct, does not correspond with the cosmical, geological, and meteorological facts it was intended to explain. Though not very familiar with geology, palæontology, or biology, I hope that, owing to the kind assistance of friends, I have been able to avoid misleading errors in that part of the matter. Several valuable treatises and other papers on geology have been consulted. I have sought throughout to do full justice to geological and biological evidence compared with that furnished by astronomy and physics.

For some leading ideas I am specially indebted to my good friends Prof. Svante Arrhenius and Dr. Gunnar Andersson.

On account of the simplicity and clearness of the metric system I have used it throughout, as well as centigrade degrees.

This paper is presented to the Royal Meteorological Society at its

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Jubilee on April 3, 1900, as a humble expression of homage and gratitude by the author.

Contents.

1. *Introduction—On the general causes of changes of temperature.*

The phenomena of weather are of four principal classes, viz. those depending (1) on heat and light; (2) on water; (3) on air movement or wind; and (4) on electricity. Of these, the first is the most important, and is generally the cause of the others, light being only a development of heat. The heat economy of nature is thus the first chapter of every inquiry on climate, and temperature is the most important element of weather and climate. Temperature being also the element most easily examined and best known, I shall confine my inquiry to it. Thus the temperature of the atmosphere, of the ocean, and of the earth's surface determines, directly or indirectly, our climate. The temperature in its turn is determined by the insolation, *i.e.* the radiating energy (heat, light, etc.) of the sun, absorbed by the earth, and by the radiation from the earth into space, these two radiations being generally equal. But if the one varies without a proportional variation of the other, the temperature, and with it the climate, of the earth will undergo a general and radical variation, and *vice versâ*.

As will be shown further on, the solar constant, *i.e.* the heat radiation of the sun, has probably not undergone any serious changes during the time our earth has been an abode for life. But on the other hand, the transparency of the atmosphere for heat radiations of different kinds, and with it also the radiation from earth into space, have no doubt varied considerably, and thus produced the great climatic changes evidenced by geology.

Purely astronomical causes, such as the secular or long periodical changes of the eccentricity of the earth's orbit and of the obliquity of the ecliptic, are to be considered only in the second place.

Adhémar, Croll, Schmick, and others have tried to explain the Ice Age, though in a somewhat different way, by the difference in length of the summer and the winter halves of the year during the periods of great eccentricity of the earth's orbit, when the difference may amount to somewhat more than a month (35 to 36 days). But this explanation is untenable, for the simple reason that the total amount of heat which the short summer of the one hemisphere receives from the sun is equal to that which the long summer of the other hemisphere receives. Now, as the summer heat of our epoch, when this season has

nearly its normal length, is more than sufficient to melt completely the winter snow in the regions of the earth which once were covered with ice, it certainly must be so even if the same quantity of heat be distributed over a somewhat shorter or somewhat longer space of time. And, in fact, the explanation of the Ice Age given by the above-named authors has not stood the test of scientific examination.[1] Yet it seems unquestionable that the long-period variations of the eccentricity of the earth's orbit, and those of the length of the four seasons following from them, will exert some influence on climate.[2] If, for instance, the summer be short and hot, and the winter long and cold, the climate will have quite a different character than if the summer be long and cool, and the winter short and mild. It will be a difference, as to temperature, essentially of the same kind as that between the climates of Siberia and of England, *i.e.* between the continental and the maritime climates. It is, however, doubtful if geologists have as yet discovered the traces of such periodical climatic changes as these, which, perhaps, are not very obvious.[3]

On the other hand, I shall prove further on that the long-period variations of the obliquity of the ecliptic have produced very marked periodic climatic changes in the north polar area, and south of it, at least as far as 55° N., and that these changes have left evident traces in the history of the earth, which already have been observed by geologists and botanists. It must be borne in mind that during the variations of the obliquity of the ecliptic the axis of the earth maintains its position in the earth itself invariable, the geographical position of any place on the earth's surface remaining undisturbed.

The case would be quite different if any considerable displacement of the axis of rotation relatively to the earth's figure had occurred. Then the climate of any place might be so radically altered that the pole, for instance, might change its climate with a place near the equator. Many geologists have supposed such changes as possible explanations of the great climatic variations of the geological past. But as the inquiries of modern geology unanimously indicate that all great climatic changes have occurred simultaneously on the whole earth, these changes cannot be explained by displacements of the poles, which would not alter the climate of the earth as a whole, but only transfer the climatic zones to other parts of the earth. Thus, even if such a displacement of the poles were mechanically possible, which is doubtful,

[1] J. Hann, *Handbuch der Klimatologie*, 2te Auflage, erster Band, Stuttgart, 1897, p. 370 and following. Also the present climatic state of the planet Mars seems to prove that a great eccentricity is unable to produce an Ice Age. For though the summer half-year of the southern hemisphere of Mars has a length of only 306 days, and that of the northern hemisphere one of 381 days, yet the white polar caps are melting away nearly completely every summer in both hemispheres. The planet passes its perihelion 36 days before the midsummer of its south pole, and the insolation in the perihelion bears to that in the aphelion a ratio of 1·45. Thus the contrast due to eccentricity is at present greater on Mars than it has ever been on the earth.

[2] J. Hann, *l.c.*

[3] According to the opinion of some geologists and botanists, especially of J. Croll and Axel Blytt, these climatic changes would also manifest themselves as changes in the rainfall, thus alternately producing dry and wet periods. As it seems to me at present impossible either to confirm or to disprove that opinion by means of physical or meteorological arguments, it may be left to future researches, and so much the more as the geological and botanical facts considered by Croll, Blytt, and their followers are still much in dispute.

we should nevertheless have no reason to enter on a discussion of that subject at present.

In the beginning, and about the middle, of this century it was a common opinion among geologists that the interior heat of the earth had materially contributed to the warm and uniform climate of the earliest geological periods. We shall see if there may possibly be any ground for this idea.

Once in primeval ages the earth must have been on the same stage of development as the planet Jupiter is at present. It was then surrounded by a very dense atmosphere, in which all water was suspended in form of vapour. The quantity of water being 244 times that of air,[1] the atmospheric pressure was then 245 times as great as at present, *i.e.* 245 atmospheres. Now, the critical temperature of water is 365° C., and the critical pressure 200 atmospheres. Accordingly, as long as the temperature of the earth's surface was above 365° C., the water immediately over it was maintained in the form of vapour, and the cooling was produced by convection by means of atmospheric currents and by thermal radiation at the upper limit of the atmosphere. Owing to the radiation, the upper strata of the vapour atmosphere were condensed to thick and perfectly opaque clouds,—as is now the case with the atmosphere of Jupiter,—and enormous showers were falling occasionally to the surface of the earth, producing spheroidal, or Leidenfrost, phenomena on a gigantic scale with violent explosions, and probably also volcanic eruptions, all which accelerated the cooling of the earth. This cooling was probably going on still faster as soon as the temperature of the surface had fallen below the critical temperature of water, for then the vapour would be condensed into a layer of water always increasing in thickness, and the atmosphere would become gradually translucid, so that heat would radiate directly from the surface of the water into space. As we know, vertical currents always arise in a mass of water heated at the bottom and cooled at the surface. These currents carry heat from below upwards, and thereby the whole ocean was rapidly cooled down to the temperature which it must finally assume as soon as equilibrium had been established between the heat received by the ocean from insolation and that lost by it by radiation into space. We find by calculation that it lasted only some hundred or at most one thousand years, till the ocean, after having taken the liquid state, was cooled down very nearly (within $\frac{1}{10}$° C.) to its final temperature.[2] Out of this time only a relatively little part was needed for

[1] According to Krümmel, the quantity of water amounts to 1285×10^6 km^3. Thus, if it were uniformly spread over the whole surface of the globe, it would have a depth of 2520 metres, and the pressure of an atmosphere is exercised by a stratum of water 10¼ metres deep. The mean depth of the present oceans is taken as 3440 m.

[2] Let m denote the mass of the ocean, T_0 its absolute final temperature, S the number of calories which the ocean receives from the sun in one year = that which the ocean at the temperature T_0 radiates into space in one year, according to Stefan's law of radiation, *log* Briggs' logarithm, M its modulus, a the time in years, and T the absolute temperature of the ocean at the time a, further $a_{1,2}$ the number of years required for cooling from the absolute temperature T_1 to the absolute temperature T_2, we shall have

$$-m dT = S\left(\frac{T^4}{T_0^4} - 1\right)da$$

from which by integration

$$a_{1,2} = \frac{mT_0}{2S}\left\{\text{arc tan}\frac{T_2}{T_0} - \text{arc tan}\frac{T_1}{T_0} + \frac{1}{2M}\log\left(\frac{T_1 - T_0}{T_1 + T_0}\cdot\frac{T_2 + T_0}{T_2 - T_0}\right)\right\}$$

cooling from the critical temperature to 100° or 90° C., the temperatures at which life could begin to exist in the water.

But the cooled ocean in its turn cooled the bottom, and this by consequence contracted much more than the inner nucleus of the earth, so that frequent fissures, and with them volcanic eruptions, arose in the crust;[1] and a part of the water was pressed down into the fissures, giving rise to a great many hot springs at the bottom of the ocean. Owing to the feeble conductivity of the crust, this state might last very long, probably many millions of years, and during that time the lowest organic life might reach a relatively high development. During all that time volcanic forces were thus very active, and caused local heatings of the lowest layers of the water, which might have been very important to the life of some inferior organisms. But certainly the volcanic forces were much too feeble to cause any sensible heating of the whole ocean.

When these conditions had continued long enough, the bottom of the ocean and the earth strata under it to a considerable depth had been cooled down to temperatures which did not further vary sensibly with time. Thus a permanent state ensued, during which the heat brought to a stratum by conduction from beneath was exactly sufficient to supply the heat lost by conduction to the upper strata, and from the uppermost conducted to the ocean. By consequence, the volcanic forces entered on a time of repose, for the crust was no longer split by contraction relatively to the nucleus. But then gradually an opposite state arose in the crust. For the inner nucleus was always losing heat, and its temperature, in consequence, continually fell, though extremely slowly, whereas the crust maintained its temperature unaltered. Con-

Now, as shown further on (Chapter 3, p. 19), we may put, corresponding to the present conditions of the earth, $T_0 = 288°$ C., and $S = 720 \times 365{\cdot}24 \times 5{\cdot}1007 \times 10^{18}$ gram-calories, $5{\cdot}1007 \times 10^{18}$ being the area of the earth's surface in square centimetres. From hence, using Krümmel's value of m given above, we find $m/S = 0{\cdot}9590$. This means that it takes 0·9590 of a year to lower the temperature of the ocean, when it is 15° C., by one degree Centigrade. Then putting $T_0 = 273 + 15 = 288°$ C., $T_1 = 273 + 365 = 638°$ C., and $T_2 = 273 + 15{\cdot}1 = 288°{\cdot}1$ C., the above formula gives $a_{1,2} = 480$ years. And for the cooling from 90° to 50° C., for instance, we find $a_{1,2} = 40$ years. In the above calculation it was assumed that heat radiated directly from the ocean into space; but, as will be shown further on (Chapter 3, p. 14), the atmosphere absorbs a considerable part of the heat radiating from the ocean, and the phenomenon is going on just as if all heat radiated into space from an atmospheric layer of considerable height, and therefore at a much lower temperature than that of the ocean. In this case, if we assume corresponding values of T_0 and S, T_0 designating now the absolute temperature of that layer, it is easily seen (cf. the explanation given below, Chapter 3, pp. 19 and 20), that the above formula still remains true if we lower also T_1 and T_2 as much as we lower T_0. Thus lowering these three temperatures by 46° C., and taking for S half the above value, which corresponds approximately to the present state of the atmosphere, we find the time required for a cooling of the ocean from 365° to 15°·1 C. to be 790 years. It is probable that the absorbing power of the atmosphere was greater then than now, owing to the great quantity of water vapour in the atmosphere, and accordingly the time required for cooling the ocean, from the critical to the final temperature, may have been somewhat more than a thousand years. But we observe that the greatest part of that time was occupied in the cooling in the vicinity of the final temperature, as indicated by the formula, and, in consequence, that the ocean did not remain practically hot for more than some hundred years.

[1] As shown by Lord Kelvin (*Mathematical and Physical Papers*, vol. iii., London, 1890, p. 312 and following), the earth's nucleus is at least as rigid as steel or glass, in spite of its high temperature. This is explained by the enormously great pressure and high temperature by which the magma, though physically fluid or gaseous, obtains a viscosity or rigidity even greater than that of a solid at ordinary temperature. As soon as the pressure is suddenly diminished by the formation of a fissure, the magma becomes really fluid in the ordinary sense and is pressed up violently.

sequently the crust now expanded relatively to the nucleus, and by the action of gravity crumples were formed on it. In this way arose the first mountains and continents, which gradually lifted themselves above the level of the ocean. We will come back to this further on.

I shall now show that the conductivity of the crust is so insignificant that the heat brought by conduction from the inner hot nucleus to the ocean and atmosphere is entirely negligible compared with that supplied by insolation, and consequently cannot produce any sensible rise of temperature. The conductivity of primitive rock is at least thrice that of stratified rocks or deposits, such as sandstone, limestone, or marble; nevertheless it also is so insignificant that the primitive rock (granite) ought to be at a red-heat (1000° C. above the surface temperature) at a depth of 30 metres,[1] in order that the yearly quantity of heat furnished from the crust should amount to as much as the solar heat absorbed by the earth's surface and the lower atmospheric strata during the same interval. For a stratified rock the corresponding depth would be scarcely 10 metres. But it is very improbable that so great a rate of increase of the temperature with depth has ever occurred. And if so, it was certainly at the time when the temperature of the crust was higher than 365° C., and all the water was in form of vapour suspended in the atmosphere. For if the ocean had remained on so thin a crust, and that beneath it had been a glowing hot mass, the crust would have been incessantly torn in pieces by volcanic eruptions and explosions, until, by the cooling influence of the water, the temperature of the upper strata of the crust had immediately fallen so much as to make the rate of increase of the temperature with depth nearly as slow as in the present time. And even if this rate had once been much greater than now, which is improbable, the quantity of heat furnished from the interior of the earth would still have been nearly negligible compared with that of the sun. If, for instance, the temperature of primitive rock at a depth of 300 metres were 100° C. above that of the surface, the heat coming from the rock would be only $\frac{1}{100}$ of that from the sun.

Thus it results from the above that during the time organic life has existed on the earth the inner heat of the globe has not been able sensibly to raise either the mean temperature of the ocean or that of the air.[2] On the other hand, local heatings, as said above, in form of hot springs both on the sea bottom and the ground, may have played a considerable part for the organisms which thrive best at a high temperature. And as undoubtedly some centuries elapsed while the ocean was cooling down, we may assume that such organisms already then began to appear in it. If it be so, they will undoubtedly represent primeval life on the earth.[3]

[1] In this calculation I have used the coefficient of conductivity 0·582 gram-calories per minute, cm. and centigrade degree determined by Prof. Th. Homén in Finland; *Der tägliche Wärme-umsatz im Boden und die Wärmestrahlung zwischen Himmel und Erde*, p. 84. Leipsic, 1897.

[2] Lord Kelvin, by a somewhat different way of reasoning, has arrived at a similar result. W. Thomson, "On the Secular Cooling of the Earth," *Transact. of the Roy. Soc. of Edinburgh*, 1862; W. Thomson and P. G. Tait, *Treatise on Natural Philosophy*, vol. i. part ii., new edition, Cambridge, 1883, p. 448; W. Thomson, *Mathematical and Physical Papers*, vol. iii., London, 1890, p. 295.

[3] According to the Danish Prof. Eugen Warming (*Lehrbuch der ökologischen Pflan-*

Finally, I shall point out a thing which possibly may have played some part in vegetation during the older geological periods. No doubt Jupiter was then self-luminous, and its surface nearly as hot as that of the sun, and the heat and light radiated from this great planet to the earth, though, of course, much feebler than that from the sun, was perhaps not quite without influence.

2. *Geological chronology—The probable duration of life on the earth.*

Before beginning the study of the history of the climate on the earth, it will be desirable to fix a tolerably reliable chronology.

If here we ask the leading geologists, the answers run as follows. From the denudating force of rivers on stratified rocks Phillips has calculated that the age of these rocks is from 38 million to 96 million years.[1] Sir Archibald Geikie[2] makes the following calculation. The rate at which stratified deposits are formed varies from 1 foot in 730 years to 1 foot in 6800 years, and as the total thickness of all such strata, where fully developed, may be estimated to about 100,000 feet, we find the time elapsed during the formation of all such strata to lie between 73 million and 680 million years; and as new strata are also to a great extent built up from the detritus of older ones, these numbers are minimum values. By also taking this latter circumstance into account J. J. Sederholm[3] found the same interval to lie between 300 million and 1000 million years.

The following calculation of the age of the ocean was made by P. Mellard Reade, and communicated by T. C. Chamberlin.[4] The present quantity of common salt (sodium chloride) in the ocean is calculated to be 35,990 billion tons, and the yearly supply from the rivers 216 million tons. Supposing the yearly supply to have been formerly the

zengeographie, Berlin, 1896, pp. 157, 158), the *Schizophyceæ* (bluish-green algæ in a very primitive stage) thrive well in hot water of a temperature above 80° C. In North America, Yellowstone Park, these algæ are growing in water at from 30° to 85° C. "Do not these colonies of primitive algæ give us a representation of the oldest vegetation of the earth?" says Warming. The still more primitive sulphuric bacteria that are growing in knolls in hot springs in Japan thrive at temperatures between 51° and 70° C. (Manabu Miyoshi, *Studien über die Schwefelrasenbildung und die Schwefelbacterien der Thermen von Yumoto bei Nikko*, reprinted from the *Journal of the College of Science*, Imp. Univers., Tokyo, Japan, vol. x. part ii., 1897). Also a veritable green alga, a variety of *Conferva major*, and accordingly a much higher organism, is growing in water of 74° C. (Josephine E. Tilden, "Observations on some West American Thermal Algæ," in *The Botanical Gazette*, vol. xxv., January-June 1898, Chicago. As to the spores of bacteria, they can support, as known, still much higher temperatures; the spores of a bacterium growing in the earth at high temperatures are killed in saturated aqueous vapour at 100° C., but only after from five and a half to six hours. In superheated steam or hot air many spores endure still much higher temperatures, and are killed at 160° to 170° C., but only after an hour (Carl Günther, *Einführung in das Studium der Bakteriologie*, Leipsic, 1895). As to degrees of cold many seeds endure, without loss of germinating faculty, a temperature of − 252° C., and probably, of course, also the absolute zero, − 273° C. (W. T. Thiselton-Dyer and Dewar, *Proc. Roy. Soc.*, 1899, vol. lxv. p. 361). Prof. G. Lagerheim, at the University of Stockholm, who has kindly afforded me the above quotations, is, however, of the opinion that no spores or seeds will be able to endure these extremes of temperature during the thousands of years comprised in a geological period.

[1] Phillips, *Life on the Earth*, Rede Lecture, 1860, p. 119, cited by G. H. Darwin in *Nature*, vol. xxxiv. 1886, p. 420.

[2] Archibald Geikie, *Report of the British Association*, Edinburgh, 1892, Address, p. 19.

[3] J. J. Sederholm in the journal *Naturen*, May 15, 1894, Helsingfors, Finland (Swedish).

[4] *Journal of Geology*, vol. vii., Chicago, 1899, p. 572.

same as now, we find from this that it has taken 166 million years for the ocean to obtain its present quantity of sodium chloride. Now, on the one hand, we might possibly suppose that the yearly supply was greater in the oldest times than now; but, on the other hand, we know that enormous quantities of salt have crystallised out from the ocean and are forming thick layers of rock-salt. Thus the calculated time is rather too short than too long.

A. G. Nathorst[1] gives us a statement that enables us to make an approximate calculation of the time elapsed since the Silurian period. The contraction of the radius of the earth, owing to the secular cooling from that epoch to the present time, is estimated to at least 5000 metres. From this we first calculate the diminution of the mean temperature of the earth during that time to be at least 16° and at most 40° C.[2] Furthermore, we may calculate that, with the present conduction of heat, it will take at least 3 million, and perhaps as much as 11 million, years, before the mean temperature of the earth is lowered 1° C.[3] Hence it follows that from the Silurian period at least 48 million and perhaps as much as 440 million years have elapsed.

Another estimation of the contraction of the radius of the earth, due to Hein, would give values more than ten times as great as the above, for according to him this contraction, during the formation of the Alps, would be as much as 57 kilometres—a value which, however, is probably too high.[4]

Lord Kelvin[5] has calculated the secular cooling of the earth in another way and obtained smaller numbers—probably about 24 million years, according to the latest published estimate; whereas his first calculation gave more than 20 million and less than 400 million years, and probably about 100 million years. But the calculation of those results is based upon the following assumptions. Lord Kelvin starts from the hypothesis that the earth was once a glowing, melted mass, having the same temperature (v_0 + V) throughout, and being continuously cooled by

[1] A. G. Nathorst, *Jordens historia*, Stockholm, 1894, vol. i. p. 331 ("History of the Earth," Swedish, partly translated from M. Neumayr, *Erdgeschichte*, 1st edition).

[2] If we suppose the coefficient of linear expansion of the earth for one degree centigrade to lie between 0·00005 and 0·00002. The former value is probably, considering the high average temperature of the earth, nearer the truth.

[3] For the calculation we ought to know the specific heat on an average for the whole earth, as well as the thermal conductivity and the rate of increase of the temperature of the crust downwards (=the geothermal gradient) on an average for the whole surface crust. The specific heat of the upper crust is about a half per unit of volume; that of the deeper layers is probably greater. I have taken a half as a minimum value. From the laws of thermal conduction it follows that the geothermal gradient, when once a permanent state has commenced, will be approximately proportional to the reciprocal value of the coefficient of thermal conductivity, and therefore we ought to use corresponding values of these two constants by calculating the average conduction through the crust; but this meets with difficulties, as the geologists ordinarily determine only the former and the physicists only the latter. The mean thermal gradient is said to be 1° C. for 25 to 33 metres, and the coefficient of the thermal conductivity may be assumed to lie between 0·001 and 0·003 $\frac{\text{gram-calories}}{\text{cm. sec.}}$, and its probable value ought to be about 0·002, *i.e.* a little greater than that of marble.

[4] *Erdgeschichte*, von Prof. Dr. Melchior Neumayr, 2te Auflage, neubearbeitet von Prof. Dr. Viktor Uhlig, erster Band., *Allgemeine Geologie*, Leipsic and Vienna, 1895, p. 382.

[5] W. Thomson, *Transact. of the Roy. Soc. of Edinburgh*, 1862; *Mathematical and Physical Papers*, vol. iii. p. 295, London, 1890; W. Thomson and P. G. Tait, *Treatise on Natural Philosophy*, vol. i. pt. ii. new ed., Cambridge, 1883, p. 448; *Nature*, vol. li. 1894-1895, pp. 438-40.

thermal conduction from the interior outwards to the surface, where the temperature is supposed to have a lower constant value v_0. Thus the geothermal gradient is supposed to have been infinitely great at the earth's surface, but zero below the surface in the initial state. In order to maintain the surface temperature at the constant value v_0, he considers empty space as a body of physical matter having the same temperature $(v_0 - \mathrm{V})$ throughout, and the same conductivity as the earth. This latter assumption, of course, was introduced only in order to supply a law for the cooling of the earth's surface by radiation or convection of heat through the ocean and atmosphere. Further, the conductivity of the whole earth was assumed to be constant. Then applying the known theory of Fourier to this simple ideal case, he finds a formula[1] indicating that the geothermal gradient at the earth's surface will incessantly diminish, with increasing time, from its initial infinite value down to the present one. Then introducing in this formula a value of $v_0 + \mathrm{V}$ equal to that of "melting rock," and taking for the present geothermal gradient in the surface $\frac{1}{51}°$ F. per foot, he obtained the above cited results.

Now for a moment accepting Lord Kelvin's final result, if we ask how long, after the initial state, the earth was fitted as an abode for life, we might perhaps assume that it was so, when the geothermal gradient of the surface had decreased to $\frac{1}{10}°$ per foot. Then we find from the formula that this decrease would take a time of only about one million years, and thus the earth would have been habitable during about 23 million years.

Every geologist and biologist will certainly think that both those periods are enormously underrated, and I shall now try to prove that they are so also on physical grounds. For this purpose we shall examine the above assumptions, from which Lord Kelvin starts.

Firstly, his law for the cooling of the earth's surface leads to a much too high rate of loss of heat, and in the initial state even to an infinite one. Lord Kelvin in his first cited paper meets this objection by the remark, that a large mass of melted rock, exposed freely to our air and sky, will, after it once becomes crusted over, present in a few

[1] The formula is—

$$\frac{dv}{dx} = \frac{\mathrm{V}}{35 \cdot 4} \cdot \frac{1}{\sqrt{t}} e^{-\frac{x^2}{1600t}},$$

where $\frac{dv}{dx}$ designates the geothermal gradient in Fahrenheit degrees per foot, V half the difference of the two initial temperatures assumed on each side of the surface of the earth, x the depth below the surface in feet, and t the time in years. Thus at the beginning of the time $\frac{dv}{dx}$ is supposed to be infinite at the surface. If t be taken sufficiently great, the exponent may be neglected, and thus the exponential taken as equal to unity for small values of x, so that the use of the formula for the purpose in question is very simple. Now if the initial temperature of the earth, $v_0 + \mathrm{V}$, be taken as equal to 7000° F., and v_0 be neglected as being nearly equal to zero, then if we put $\frac{dv}{dx} = \frac{1}{51}$, which is supposed to be the present value of the geothermal gradient in the surface (according to the observations), the formula gives $t = \left(\frac{7000 \times 51}{35 \cdot 4}\right)^2$ = nearly 102 million years. In this way Lord Kelvin deduced the value of "about 100 million years." But afterwards taking for $v_0 + \mathrm{V}$ only about 1200° C., and taking into account also the effect of pressure on the temperature of solidification, he obtained a value about four times less, which is his final result.

hours, or a few days, or at most in a few weeks, a surface so cool that it can be walked over with impunity. To this I remark that this was not so, until the earth's surface had already been cooled down so much, that the water had been condensed on it, and then the temperature of the crust was not higher than 365° C. or 689° F. Before that time the earth, as remarked above, was surrounded by a very dense and opaque atmosphere, just as Jupiter is now, and the loss of heat from the earth's surface was produced only by convection through the atmosphere and radiation at its upper limit, where the temperature was very low, and thus the loss of heat by radiation very little. Thus when the surface of the earth was cooling down from 7000° F., say, to 689° F., the loss of heat by convection and radiation was certainly incomparably much slower than according to Lord Kelvin's assumption, and thus also the time required for this cooling much longer than one million years.

We shall now consider the first of Lord Kelvin's assumptions, viz. that the earth in its initial state, or "*Consistentior Status*," had a uniform temperature throughout.

According to the nebular hypothesis, now generally accepted, the earth, as well as the other celestial bodies, was once a glowing gaseous mass. In that state of the earth its temperature certainly increased enormously from the surface to the centre. For heat was carried from the centre to the surface by convection, and as the pressure increased downwards, the matter, when sinking down, was heated by compression, and, when rising, was cooled by expansion. Also the surface, and the surface only, was cooled by radiation. In this way the gaseous globe incessantly lost heat, but, nevertheless, its inner temperature was continually rising, owing to the heat generated by contraction, just as, according to the theory of Helmholtz, the sun's heat is maintained in this manner.[1] When this process had been going on sufficiently long, the increasing temperature, pressure, and density of the nucleus produced so great a viscosity or rigidity in the gaseous mass, that the convectional currents were stopped, and then the surface layers relatively soon cooled down to a low temperature, so as to cover the nebula with a solid crust surrounded by a dense atmosphere. For the thermal conduction is much too slow to restore to the surface the heat lost by radiation. But just on account of the slowness of thermal conduction the inner nucleus maintained its enormously high temperature, or even grew hotter and hotter by self-compression, and, its temperature being much above the critical point, it remained in the gaseous state, *i.e.* conserved its perfect elasticity, though its viscosity or rigidity finally became equal to that of glass or steel. Such is, according to the modern view of physicists, the constitution of the earth's nucleus still to-day, and its present central temperature is estimated to about 100,000° C.[2] Only the crust, to a depth of perhaps 60 or 70 kilometres, can be in the solid state, but the underlying gas is, owing to the enormous pressure

[1] According to the calculations of J. H. Lane and Lord Kelvin, considered in a following chapter, the central temperature of a gaseous nebula is about 22½ times higher than its average temperature, which is found to increase with time as the reciprocal of the radius of the nebula.

[2] See, for instance, S. Günther, *Handbuch der Geophysik*, Erster Band, p. 344 and following, Stuttgart, 1897.

and temperature, quite as rigid as a solid. Thus when the solidification of the crust took place, fragments of the shattered crust could not sink down in the inner nucleus, for this was already then about as rigid as glass or steel, and, moreover, much denser than the crust. In those points the views of Lord Kelvin were, in 1862, quite different, and he still seems to be of the opinion that the whole earth may be actually a kind of honey-combed solid and liquid mass of a nearly uniform temperature. But this view must now be considered as extremely improbable, since the numerous experiments of a great many physicists on the critical temperature and pressure, and especially the recent inquiries of Tammann on the constitution of matter at great pressures, have shown that neither the liquid nor the solid state can exist at very high pressures and temperatures.

Thus we must assume as the most probable case, that the inner nucleus of the earth in its "*Consistentior Status*" had a temperature of about 100,000° C. or 180,000° F. Now if this temperature be taken as the initial value of V in Lord Kelvin's formula instead of 7000° F. or 1200° C., and we by means of it calculate the time required for diminishing the geothermal gradient at the earth's surface from $\frac{1}{10}$° to $\frac{1}{51}$° per foot, then this time may be considered as an approximate value of the time during which the earth has been an abode fitted for life. Doing this we get as the age of life on the earth *many thousand million years*.[1] Such a value, which is deduced from Lord Kelvin's formula with the most probable value of the central temperature of the earth, will no doubt satisfy the requirements of geologists and biologists.

But if the geothermal gradient were really a measure of the earth's age, even such a gigantic number might be too small. For heat was generated, and is no doubt still generated, in the interior of the earth mechanically by its slow contraction, and this will probably suffice to maintain its inner temperature nearly constant during untold million years.[2] This circumstance alone would suffice to maintain the geothermal gradient at the surface constant during all the time this process is going on.

Also Lord Kelvin supposed the thermal conductivity of the earth to be constant. This assumption may be approximately true, if we assume, with him, the thermal state of the earth to be essentially variable, as presupposed in the formula. For then we must introduce in the formula the thermal conductivity measured in terms of the

[1] We find

$$t=\left(\frac{180,000}{35\cdot4}\right)^2(51^2-10^2)=64,700,000,000.$$

By this use of Lord Kelvin's formula we do not assume an initial uniform temperature through the whole earth, for we start from the initial state of a surface gradient of $\frac{1}{10}$° per foot, and then the formula indicates continual increase of temperature from zero at the surface to 180,000° F. at the centre; as it ought to be. As remarked by Lord Kelvin, his formula is deduced irrespectively of the earth's curvature, but at least during the first 1000 million years the variation of temperature does not become sensible at depths exceeding one-seventh of the earth's radius, and is therefore confined to so thin a crust that the influence of curvature may be neglected (*Math. and Phys. Papers*, *l.c.*, p. 302). And even during the first 10,000 million years the variation of temperature would be nearly insensible at depths exceeding one-third of the earth's radius.

[2] To a certain epoch the self-compression will even raise the temperature, then the temperature will remain very nearly constant during long ages, and finally very slowly decrease.

thermal capacity of unit of bulk.[1] But, as just shown, the thermal state of the inner nucleus of the earth is probably very nearly constant during untold million years, and the formula does not apply to such a permanent state, but only to a variable one. But for a permanent state we must calculate with the absolute conductivity, and this is at least thrice as great for primitive rock as for stratified deposits. Now nearly the whole surface of the earth is covered with thick layers of such deposits lying on primitive rock. But on account of the relatively great conductivity of the latter a great deal of heat is constantly carried to the inner surface of the stratified deposits, whereas their upper surface is constantly cooled by radiation and convection by air and water currents, so as to maintain its temperature very nearly equal to that of those currents. Hence it follows from the known laws of thermal conduction, that the stratified deposits will very soon after their formation be traversed by a regular flux of heat, forming a geothermal gradient proportional to the reciprocal value of the absolute conductivity of the stratified deposit, but independent of its age. Also it seems to me that this conclusion is verified by the observations, for the less the conductivity of a stratum is, the greater is generally the increase of heat in it with the depth, quite independently of its geological age.[2]

[1] Let κ be this conductivity, c the specific heat per unit of mass, δ the density, *i.e.* mass per unit of bulk, and k the absolute conductivity, *i.e.* the number of calories passing in unit of time through the unit of surface of a layer, the thickness of which is the unit of length, and the limiting surfaces of which are maintained at constant temperatures, differing by one degree, then

$$\kappa = \frac{k}{c\delta}.$$

[2] Thus in the Swedish iron mines the geothermal gradient is generally not more than $\frac{1}{50}$° C. per metre, or even less, in the artesian wells it is from $\frac{1}{35}$° to $\frac{1}{15}$°, and in coal mines even from $\frac{1}{14}$° to $\frac{1}{11}$° C. per metre. But as the geologists do not generally determine the conductivity of the strata, the geothermal gradient of which they measure, I cannot verify the above statement more in detail. I give here some values of absolute conductivity in the units of the Centimetre-Gramm-Second-System in order to prove the statement in a general way:—

Matter.	Absolute Conductivity.	Authority.
Pit-coal	0·000297	Neumann.
Slate	0·00081	Forbes.
Marble, white	0·00115	*Id.*
Marble, black	0·00177	*Id.*
Primitive rock	0·00970	Homén.

Lord Kelvin communicates in *Nature*, vol. li. p. 439, some values of thermal conductivity, due to R. Weber, and probably expressed in the above units. Also those values indicate the same fact, quartz having a much greater conductivity than the other minerals.

To those numbers it ought to be remarked that they, of course, apply only to ordinary temperatures. But in measuring the geothermal gradient in the earth's crust the observers did not in the greatest depths reached in mines and wells find temperatures exceeding 50° C. Thus the above numbers are applicable to the strata, where the geothermal gradients were observed. But if we calculate the geothermal gradient in the interior of the earth, where the temperature and pressure are very high, then we must confess that we know very little about the thermal conductivity of the matter there. It may be that the thermal conductivity of slate, sandstone, and granite is probably somewhat less at higher temperatures than at lower, as Lord Kelvin states (*l.c.* p. 439). But already in a depth of 60 or 70 kilometres (only about $\frac{1}{100}$ of the earth's radius) the temperature and pressure will be so high (temperature about 2000° C. and pressure about 10,000 atmospheres), that heat will be generated there or in a somewhat greater depth by the slow contraction of the crust. Thus the absolute conductivity in those depths is of little importance for the problem dealt with, though this conductivity probably still is greater than that of most stratified deposits at ordinary temperature.

According to Lord Kelvin there are some eruptive rocks of so recent origin that the permanent state has not yet set in, and thus their geothermal gradient is unusually great.

And in no case has the temperature of a stratified deposit decreased from its formation to the present time, for during its formation it had the same temperature as the water in which it was formed, and afterwards it was heated by thermal conduction from the ground, until the permanent state commenced.

I think the reasons adduced above will suffice to prove the probability of an already primeval, nearly permanent, state in the conduction of heat through the earth's crust. Hence it follows, that the geothermal gradient is not at all a measure of the earth's age, which for this quantity might be geologically nearly unlimited.

Thus I venture to say that the above method of calculation, used by myself, and founded upon the assumption of an already primeval permanent state in the geothermal gradient of the uppermost strata of the crust, is essentially correct, though the result obtained is, of course, uncertain, on account of the uncertainty of the physical constants employed.[1] There is, however, strong reason to believe that the limiting values of 48 million and 440 million years respectively, which I have found, are too small. For the heat generated by the earth's contraction enters into the calculation in the same manner as the specific heat of the earth, and thus increases the age calculated. If the heat of compression were, for instance, equal to the earth's own provision of thermometrical heat, the numbers found above ought to be doubled, and thus there would have elapsed between the Silurian and the present epoch at least 96 million and perhaps as much as 880 million years. The limiting numbers found by my calculation from the secular cooling of the earth are thus of the same order of magnitude as those obtained by geologists by means of quite different methods,[2] and thus we shall probably not err very much if we say that the age of life on the earth amounts to at least 100 million and perhaps to 1000 million years.[3]

In a popular lecture delivered by H. Helmholtz[4] at Königsberg in 1854 he calculated that since the beginning of the solar system the sun had generated by contraction, and lost by radiation, 28 million units of heat (centigrade) for each unit of its mass. Now, according to S. P. Langley, the sun's annual loss of heat by radiation amounts to somewhat more than two such units of heat per unit of mass, and thus the sun's provision of energy would only suffice for scarcely 14 million years, assuming the present rate of loss by radiation also for previous time, or, if the loss formerly were less than now, possibly some million years longer. But Helmholtz, in making this calculation, took into

But such exceptional cases are so rare that they are of no practical importance for the secular cooling of the earth. Sir W. Thomson, "On the use of Terrestrial Temperature for the Investigation of Absolute Dates in Geology," in *British Association Report*, 1855, part ii., reprinted in *Mathematical and Physical Papers*, vol. ii. p. 175, Cambridge, 1884.

[1] The greatest uncertainty is no doubt due to our ignorance of the real contraction of the earth's radius during geological time. But judging from the crumpling of the crust the value (5000 m.) given by Neumayr and Nathorst is no doubt too small, and thus the calculated time probably too short.

[2] The numbers found by Phillips, Archibald Geikie, Sederholm, and Mellard Reade are to be reckoned from the Precambrian or Cambrian time, and those found by myself from the Silurian; but this circumstance will be of no practical importance in dealing with such approximate methods of calculation.

[3] Archibald Geikie, *British Association Report*, Dover, 1899, Address to the Geological Section, p. 12.

[4] H. Helmholtz, *Ueber die Wechselwirkung der Naturkräfte, etc.*, Königsberg, 1854.

account only the work done by gravity in compressing the solar nebula, but not that done by the chemical and other molecular forces. Now, on the one side, these forces act only at very small distances, viz. between adjacent molecules and atoms; but, on the other hand, when they act at these microscopic distances they are enormously strong, a thousand, and perhaps even a million, times greater than gravity. Thus they must not be neglected, and though we do not know the intensity and radius of action of these forces so exactly that we are able to calculate the work done by them in the same way as that done by gravity, we may without hesitation estimate the work at least as ten times as much as that done by gravity, and accordingly replace the number of Helmholtz by at least 200 or 300 million units of heat (centigrade) per unit of mass of the sun.[1]

I have wished to show by the above that no valid reasons against the estimate of the age of life on the earth made by geologists and biologists can be taken from the laws and facts obtained from physical researches. It also seems to me that the geological and biological facts on which this estimate is founded are at least as reliable as the physical constants and assumptions on which a calculation of the secular cooling of the earth or the heat store of the sun are based. Still much more unreliable are the calculations of the earth's age founded on a hypothesis as to the mode of formation of the moon or the tidal friction exercised by it on the earth. For as long as Laplace's nebular hypothesis has not been verified by an exact mathematical analysis in all its consequences and details, we know nothing about the age of the moon as a satellite of our earth.

3. *The radiation of the sun nearly constant during geological ages.—The temperature at the earth's surface explained by the equilibrium between insolation and radiation from the earth into space.*

The nebular hypothesis for explaining the origin of the solar system, which was first set up by Emanuel Swedenborg in 1734, and then later developed by Immanuel Kant and in a more scientific form by Laplace, has gained a high degree of probability by the astronomical observations on nebulæ inaugurated by William Herschel, and so successfully carried on by means of the telescopic, photographic, and spectroscopic methods of modern astronomy. Nowadays we know that the immense universe is studded with innumerable nebulæ, which undoubtedly are the primitive stage of stars or solar systems. Some of them consist only of gaseous matter without definite outlines, others show already condensed portions, and a few are even well-defined stars surrounded by nebular matter. Most nebulæ exhibit a flattened spiral structure, thus indicating a rotatory motion. This hypothesis on solar evolution was completed in 1854 by Helmholtz,[2] who by his celebrated contraction

[1] The importance of the molecular forces for the store of energy of the sun has been particularly pointed out by Faye (*Comptes rendus, passim*). My friend Prof. Svante Arrhenius has made a calculation, not yet published, on this matter, and arrived at the result that the original store of potential energy in the sun owing to chemical forces was even much greater than according to the above estimate.

[2] H. Helmholtz, *l.c.*

theory showed that also the heat and light of the sun and the other stars may be explained as generated by the work done by the contraction. I have remarked above that the explanation of Helmholtz is incomplete, as he takes into account only the work done by gravity. But if this want be supplied by taking into account also the chemical, molecular, and other forces, if such exist, acting between the particles of matter, the theory given by Helmholtz will no doubt satisfactorily explain the provision of energy stored up in the sun, and will be found sufficient for the wants of geology.

The size of the sun is constantly decreasing, as, according to Helmholtz's theory, the sun is shrinking—so slowly that its apparent diameter will not diminish by $\frac{1}{10}$ second of arc in ten thousand years, if my estimate of its potential energy already given is correct. According to Helmholtz himself, the diminution would go on about ten times faster. As the angular momentum,[1] according to a known mechanical law, must remain constant during the contraction, we conclude that the sun has never reached as far as to the orbit of Mercury, the moment of rotation of which in its orbit around the sun is about 1900 times greater than that of a point of the sun's surface. The radius of the sun can therefore never have been more than about 60 times greater than at present.

Now, if the temperature on the sun's surface had been constant during geological ages, it would have been at this early stage as high as it is at present, and hence the surface being then 3600 times greater than now, it would follow that the total amount of insolation must also have been then 3600 times greater than at present. But this is quite inadmissible. For life cannot have begun on the earth before the insolation had sunk to about the double of its present value (which with the present state of the atmosphere would produce a mean temperature on the earth's surface of nearly 70° C.), and the higher life can scarcely have begun before the insolation had sunk to about $1\frac{1}{2}$ of its present value (which with the present state would produce a mean temperature of nearly 46° C.).[2] Thus when it had been possible for life to begin on earth, the greatest part of the sun's heat store would already have been spent; and we find by calculation[3] that the age of life would be reduced to about 2,600,000 years, and that of higher life to about 1,800,000 years, if we assume Helmholtz's value of the heat store of the sun, or about ten times as much if we adopt my estimate. Also the whole age

[1] Let r be the distance of a particle from its centre of rotation and w its angular velocity, then the angular momentum, or moment of rotation, of the particle is wr^2. That $wr^2 =$ constant is the same mechanical law as the law of Kepler about the constancy of areas in a planetary orbit.

[2] The method of calculating these temperatures will be given further on.

[3] If t be the time in years and r the radius of the sun, then assuming that the work done by gravity be equal to the energy lost by radiation, we have

$$dt = c\frac{dr}{r^4},$$

c being a constant. Integrating and determining c by means of the condition, according to Helmholtz's and Langley's results, that the sun's radius is diminishing by $\frac{1}{10000}$ in 1200 years owing to the loss of heat by radiation, we find, if the present value of r be designated by r_0,

$$t = 4,000,000\left(1 - \frac{r_0^3}{r^3}\right).$$

of the solar system would be only 4,000,000 years according to Helmholtz's result, and 40,000,000 years according to my estimate. Thus the supposition of a constant temperature of the sun's surface during the geological ages would lead to so great a waste of the solar energy and thus to so short a time for the evolution of the solar system that it must be rejected merely for this reason.

Still more will this be the case with any hypothesis according to which the temperature of the sun's surface was in former times higher than now and decreasing up to the present time. Thus, for instance, the hypothesis of Eug. Dubois [1] is quite untenable. According to him,[2] the sun was, during the greatest part of geological ages, a white star, hotter than it is now, and then, during the Ice Age, it became suddenly a red star of lower temperature than the present one, and finally turned into its present condition of a yellow star of a middle temperature. Now, according to the estimate of J. Scheiner,[3] the surface temperature of a white star (I. spectral type) amounts up to about 15,000° C., that of a red one (III. spectral type) only to 3000° or 4000° C., that of a yellow one (II. spectral type) having an intermediate value. And according to my calculation, adopting Langley's value of the solar constant and Stefan's law of radiation, the actual temperature of the sun's surface is 6600° C. absolute. Thus the surface temperature of a white, a yellow, and a red star will be approximately as $2:1:\frac{1}{2}$, and hence, according to Stefan's law of radiation, the radiating power per unit of surface as $2^4:1:(\frac{1}{2})^4$, *i.e.* as $16:1:\frac{1}{16}$. But if the radiating power of the sun were 16 times as great as its present value, the mean temperature on the earth would be as high as about 576° absolute, or 303° C.; and if it were only $\frac{1}{16}$ of the present value, this temperature would be as low as about 144° absolute, or − 129° C. Thus in neither case could life exist on the earth.

Thus there can be no doubt that the temperature of the sun's surface increases with time as the sun contracts, and thereby the area of its radiating surface decreases. And in fact the physical inquiry into the problem has also led to this same conclusion.

Such inquiries have been made by J. H. Lane,[4] A. Ritter,[5] and Lord Kelvin,[6] and I have tried to work out these inquiries further and draw some consequences therefrom.[7]

The three physicists above-named start from the following assumptions. A nebula or a sun is a mass of glowing gas which, according to the theory of Helmholtz, is heated by the work done by gravity in contracting it, and loses heat by radiation from its surface. The heat generated in the interior is carried to the surface by convectional currents, of which the temperature is calculated according to the mechanical theory of heat as a function of the pressure or the density of the gas, assuming for the relation between temperature, pressure,

[1] Eug. Dubois, *The Climates of the Geological Past*, etc., London, 1895.
[2] *l.c.* p. 99.
[3] J. Scheiner, *Sitz. ber. d. Berlin. Akad.* 1894, Nr. 12, 257.
[4] J. H. Lane, *Amer. Journ. of Science and Arts*, 2 Ser., 50, 1870, p. 57.
[5] A. Ritter, *Wied. Ann.* 5-20, 1878-82 (several papers).
[6] W. Thomson, *Proc. of the Roy. Soc. of Edinburgh*, vol. xiv., 1886-87, pp. 111, 118.
[7] Nils Ekholm, "Ueber den Energie-Vorrath, die Temperatur und Strahlung der Weltkörper," in *Bihang till K. Sv. Vet.-Ak. Handl.* Bd. 26, Afd. I., No. 1, Stockholm, 1900.

and density (or volume) the laws of Mariotte and Gay-Lussac. This gives the result that the absolute temperature of the sun, when contracting, will increase with time as the reciprocal of its radius; and as, according to Stefan's law, the radiation per unit of surface varies as the fourth power of the absolute temperature, it follows that the total amount of insolation will increase with time, as the sun contracts, as the square of the reciprocal of its radius. This, of course, would be so speedy an increase of the insolation, and thus presuppose so feeble an insolation in ancient times, that it is inadmissible on geological grounds. But it is also inadmissible on physical grounds. For we know from physical experiments that Boyle's law is not valid at pressures of more than one or two hundred atmospheres, whereas the pressure in the interior of the sun amounts to thousands of million atmospheres.[1] Thus we conclude that the above result will be true only as long as the gaseous nebula is very thin and has an enormously great volume. As to the sun, the result has never been exactly true; for, as stated above, the sun cannot possibly have had a radius more than sixty times greater than the present. But we may assume that the result was approximately true during the first stage of the sun's evolution, and thus that the insolation was then rapidly increasing. But after a relatively short time the increase must stop and the insolation become approximately constant. For though we cannot at present solve the proposed problem rigorously by introducing the true and general equation of the gaseous state of matter instead of the equation of Boyle-Charles, we can find from approximations that the increase of the sun's temperature must go on much slower than it would do according to the above simple solution. Moreover, the convection of heat from the inner parts to the surface will be gradually retarded as the sun grows hotter and denser. For the inner friction of a gas increases rapidly with temperature, and the astronomers best acquainted with solar physics are of the opinion that the gaseous matter of the sun within the photosphere is at present at least as viscous as honey or tar. Thus the surface temperature, and accordingly the radiation from the surface, will increase much less rapidly than the inner or mean temperature of the sun. Considering all this, it will seem probable that the total amount of insolation increased during the first stage of the sun's evolution, but that this increase gradually became slower and that the insolation has been nearly constant during all the time life has existed on the earth. We may assume that the insolation has varied from the Archæan to the present time perhaps as much as from the half of its present value up to this. But there is no reason to assume long periodical variations of greater amount. And certainly the great climatic changes revealed by geological inquiries cannot be attributed to any such variations of insolation.

But, as already remarked in Chapter 1, the temperature of the earth's surface is a function not only of the insolation, *i.e.* supply of heat, but also of the radiation from earth into space, *i.e.* loss of heat, and the latter will vary considerably if the transparency of the atmo-

[1] The absurd consequences following from the Lane-Kelvin theory, if applied without limitation to the state of the sun, have been clearly formulated by T. C. Chamberlin, *Science*, N.S., vol. ix. pp. 889-901, 1899; and vol. x. pp. 11-18, 1899.

sphere for heat radiations of different kinds varies. Practically a variation of the transparency of the atmosphere will have nearly the same effect as a variation of the solar constant, and according to this we can find a very simple method of approximately calculating the mean temperature of the earth's surface under different conditions. This will now be shown.

We know that the sun is practically the only source of warmth to provide the atmosphere, the ocean, and the earth's surface with their store of heat. Compared with it both the inner heat of the earth and the radiating heat of the stars are quite insignificant. From the observations on nocturnal radiation made by Liais, Langley[1] has calculated that the temperature of empty space is $-268°$ C., or $5°$ C. absolute. According to S. Newcomb, the light of the sun is 31 million times stronger than that emitted from all stars, and hence, assuming that the radiant heat is proportional to the radiant light, I find, by means of Stefan's law of radiation, that the mean temperature of space, owing to the radiation of stars, is about $4°$ C. absolute, a value which nearly agrees with Langley's result. Thus the heat radiation of space is so insignificant that it may be neglected without sensible error.

Knowing the temperature of space, we may now calculate the earth's loss of heat by radiation into space. Let U be the radiation from a warmer to a colder body during 24 hours in gram-calories per square centimetre, then, according to Stefan,

$$U = 0{\cdot}0000001045(T^4 - t^4),$$

T designating the absolute centigrade temperature of the warmer and t that of the colder body, when both bodies are perfectly black.[2]

Tabulating this formula, putting for t the value $5°$ or $4°$ C. absolute (which may be neglected), we find :—

TABLE I.—Loss of Heat by Radiation into Space from a perfectly Black Body of the Temperature $t°$ Centigrade. In Gram-Calories per Square Centimetre during 24 Hours.

t	Loss of Heat.	t	Loss of Heat.	t	Loss of Heat.
100°	2023	20°	770	− 60°	215
90	1816	10	670	− 70	178
80	1624	0	581	− 80	145
70	1447	− 10	500	− 90	117
60	1285	− 20	428	− 100	94
50	1138	− 30	365	− 110	74
40	1003	− 40	308	− 120	57
30	881	− 50	259	− 130	44

For the low temperatures above tabulated we may assume, without sensible error, that clouds, atmosphere, ground, water, ice and snow,

[1] S. P. Langley, "The Temperature of the Moon," *Mem. of the Nat. Academy*, vol. iv., 9th mem., 1890, p. 206 and following.

[2] A newer determination of the constant of Stefan's formula, due to Kurlbaum, gives the value 0·0000001106. The difference is of no or little importance. I have used the above value.

etc., radiate as much heat as black bodies, and thus that this table is to be applied, without correction, to the radiation of the earth.

Now, as the mean temperature of the earth's surface remains very nearly constant during hundreds of years, the loss due to radiation must be equal to the gain of heat due to insolation. But this gain cannot be directly determined by experience; for though we know approximately the total amount of insolation falling on the earth's surface by the experiments of Langley and others, we do not know how much of it is absorbed. In fact, a considerable part of the solar rays is reflected back into space without being absorbed. The clouds, atmosphere, ground, water, and ice, though very nearly black for the radiation from the earth, are not so for the solar rays; or, in other words, the earth has a great albedo, the value of which is very imperfectly known, for the solar radiation.

According to Langley, the solar constant amounts to 3 gram-calories per square centimetre during a minute, which corresponds to an average for the whole earth of 1080 gram-calories per square centimetre during 24 hours. If all this heat were absorbed, the loss of heat, according to Table I., would also be 1080 calories; and we find by interpolation in the Table that the mean temperature of the earth's surface would be 46° C. Now the actual mean temperature of the earth's surface, derived from meteorological observations, is 15°·1 C., which, according to the table, corresponds to a daily mean quantity of heat absorbed equal to 720 calories, or only two-thirds of what it would be according to Langley's value of the solar constant.

The temperatures given above (pp. 15 and 16) for different values of insolation have been calculated by means of Table I. or by Stefan's formula in the manner here explained.

All the above calculations have been made as if the earth's surface were the only matter absorbing, emitting, and reflecting heat. This, of course, is only a first approximation, for the atmosphere plays a great and very complicated part in the phenomenon. An elaborate inquiry on this complicated phenomenon has been made by Svante Arrhenius.[1]

The result of that inquiry may be summed up as follows. The atmosphere plays a very important part of a double character as to the temperature at the earth's surface, of which the one was first pointed out by Fourier, the other by Tyndall. Firstly, the atmosphere may act like the glass of a green-house, letting through the light rays of the sun relatively easily, and absorbing a great part of the dark rays emitted from the ground, and it thereby may raise the mean temperature of the earth's surface. Secondly, the atmosphere acts as a heat store placed between the relatively warm ground and the cold space, and thereby lessens in a high degree the annual, diurnal, and local variations of the temperature.

There are two qualities of the atmosphere that produce these effects.

[1] Svante Arrhenius, "Ueber den Einfluss des atmosphärischen Kohlensuäregehalts auf die Temperatur der Erdoberfläche," in *Bih. till K. Iv. Vet.-Akad. Handl.* Bd. 22, Afd. I., No. 1, Stockholm, 1896; "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground," in *Phil. Mag.* for April 1896, p. 237; "Naturens värmehushållning" (Heat Economy of Nature), in *Nordisk Tidskrift*, Stockholm, 1896, p. 121; "Les oscillations séculaire de la température à la surface terrestre," Extrait de la *Revue générale des Sciences* du 15 Mai 1899, Paris, 1899.

The one is that the temperature of the atmosphere generally decreases with the height above the ground or the sea-level, owing partly to the dynamical heating of descending air currents and the dynamical cooling of ascending ones, as is explained in the mechanical theory of heat. The other is that the atmosphere, absorbing but little of the insolation and the most of the radiation from the ground, receives a considerable part of its heat store from the ground by means of radiation, contact, convection, and conduction, whereas the earth's surface is heated principally by direct radiation from the sun through the transparent air.

It follows from this that the radiation from the earth into space does not go on directly from the ground, but on the average from a layer of the atmosphere having a considerable height above sea-level. The height of that layer depends on the thermal quality of the atmosphere, and will vary with that quality. The greater is the absorbing power of the air for heat rays emitted from the ground, the higher will that layer be. But the higher the layer, the lower is its temperature relatively to that of the ground; and as the radiation from the layer into space is the less the lower its temperature is, it follows that the ground will be hotter the higher the radiating layer is.

Now if we are able to calculate or estimate how much the mean temperature of that layer is lower than the mean temperature of the ground, we may apply Table I. for calculating the mean temperature of the ground, as soon as we know by direct measurements the quantity of solar heat absorbed by the ground. Owing to the clouds and dust floating in the atmosphere, this heat is probably only about a third of that derived by using Langley's solar constant; and is thus about 360 calories per square centimetre during twenty-four hours. This gives, by means of Table I., a temperature of -31° C. to the radiating layer. But, according to Arrhenius's estimate, this is at a height of about 7600 metres;[1] and assuming a decrease of the temperature with the height of $0^\circ\cdot 6$ C. per 100 metres, we find its temperature to be 46° C. lower than that of the ground, and thus the mean temperature of the ground equal to 15° C., as it is according to the observations. This example, of which the numbers given do not pretend to be exactly true, shows the method of calculation. We see from it that both the absorbing power of the atmosphere for the heat radiation of the ground, and the quantity of clouds and dust in the atmosphere play an important part as regards the temperature of the ground. By the former the temperature is raised, by the latter it is lowered. We shall now enter more fully on the consequences of this important question.

4. *Variations in the quantity of carbonic acid of the atmosphere, the principal cause of the great climatic variations during geological ages.*

Among all the numerous hypotheses[2] imagined in order to explain the great climatic changes of the geological ages, that worked out by

[1] For the carbonic acid alone at 15,000 metres, and for the water vapour alone at 233 metres on an average.

[2] An elaborate study of the historical part of this question has been made by Luigi de Marchi, "Le cause dell' era glaciale," premiato dal R. Istituto Lombardo, Pavia, 1895.

S. Arrhenius[1] on the ground gradually laid by Fourier, Pouillet, Tyndall, Langley, Knut Ångström, Paschen, and others is the only one which has stood the test of a scientific examination. It is founded on the fact that carbonic acid, though as transparent as pure air to the solar rays, is partly opaque to the heat radiating from the ground and the lower and warmer strata of the atmosphere. Owing to this the carbonic acid in the atmosphere acts as the glass of a green-house, letting through the solar rays, but partly retaining the dark rays emitted from the ground. Thus, if the quantity of carbonic acid in the atmosphere increases, the temperature of the ground and the lower atmospheric strata will be raised, till the increase of radiation into space caused by the increase of temperature has restored the equilibrium between gain and loss of heat. But to this is added a circumstance which considerably adds to the influence of the carbonic acid. Aqueous vapour possesses the same remarkable property as carbonic acid, and is nearly transparent to solar heat, and nearly opaque to terrestrial heat. Aqueous vapour alone is, however, unable to produce any radical change of climate. For the quantity of aqueous vapour in the atmosphere is itself depending upon the temperature of the air; if this be lowered by some cause, for instance by radiation, the aqueous vapour is partly condensed and separated from the atmosphere, whereby its protecting influence is diminished, and then the increased radiation causes a new condensation of vapour, and so on. It is, therefore, only in regions and seasons already favoured by nature with a warm and damp climate that aqueous vapour alone is able to play the part of green-house glass; whereas in cold and dry regions, where the protection is most needed, aqueous vapour fails.

The case will be quite different when the carbonic acid comes into play. This gas is not condensed at any temperature occurring in the lower strata of the air. Its protecting power is thus equally active in all climates. If now the quantity of carbonic acid increases, the temperature, as already stated, will rise. But thereby also evaporation, and, of course, the quantity of aqueous vapour in the air, will be increased, by which the radiation from earth into space will be still diminished. Accordingly, the temperature will be further raised, and thus also evaporation and aqueous vapour in the atmosphere increase, and this will continue till the increase of radiation into space puts an end to the rise of temperature. In this manner the protecting influence of carbonic acid is considerably augmented by the co-operation of aqueous vapour. The chief results of Arrhenius's calculation are contained in Table II. This table was calculated chiefly by means of Langley's measurements of the heat radiation of the moon. A new determination of the absorbing power of carbonic acid at low temperatures just made by Arrhenius and not yet completely calculated, seems to lead to results not differing materially from those of Table II.

If the quantity of carbonic acid varies by a geometrical series, the temperature will vary approximately by an arithmetical one.

Now if we remember how insignificant is the present quantity of carbonic acid in the atmosphere we shall be surprised at the great effects produced by halving or doubling it. In the former case we should have

[1] Svante Arrhenius, *l.c.*

a lowering of the temperature by 5° to 6° C., which is more than is needed in order to change the climate of the earth to that which prevailed during the Great Ice Age. The snow-line is then estimated to have been about 1000 metres lower than now, and this corresponds to a lowering of the temperature equal to 4° or 5° C.

TABLE II.—VARIATION OF THE MEAN YEARLY TEMPERATURE OWING TO A GIVEN VARIATION OF THE QUANTITY OF CARBONIC ACID IN THE ATMOSPHERE.

The present quantity of carbonic acid = 1 ; + signifies rise, - fall of the temperature. Centigrade degrees.

Latitude.	Quantity of Carbonic Acid.				
	⅔	1½	2	2½	3
65° N.	-3·1°	+3·5°	+6·1°	+8·0°	+9·3°
55	-3·2	+3·6	+6·0	+7·9	+9·3
45	-3·3	+3·7	+5·9	+7·7	+9·2
35	-3·3	+3·5	+5·7	+7·4	+8·8
25	-3·2	+3·5	+5·3	+6·9	+8·1
15	-3·1	+3·3	+5·0	+6·5	+7·5
5	-3·0	+3·2	+4·9	+6·4	+7·3
5° S.	-3·0	+3·2	+5·0	+6·5	+7·4
15	-3·1	+3·2	+5·1	+6·7	+7·6
25	-3·2	+3·3	+5·4	+6·9	+8·2
35	-3·3	+3·5	+5·6	+7·3	+8·8
45	-3·4	+3·7	+6·0	+7·9	+9·3

On the other hand, a tripling of the quantity of carbonic acid would raise the temperature by from 7° to 9° C., which would suffice to give to South Sweden (55° N.) the climate of North Italy, and to Italy that of the Torrid Zone. The Polar Regions would thereby obtain a temperate climate.

There are several reasons, however, to believe that the influence of the quantity of carbonic acid of the atmosphere on the mean temperature of the ground may be in certain instances still greater than according to the Table just given, as Arrhenius himself remarks, at the end of his first-mentioned paper. The latest measurements of the decrease of the temperature with the height, made in France and Germany, have shown that this decrease is probably much greater in the middle latitudes of Europe than Glaisher's observations indicate. Hence it follows, according to the deduction on page 20, that also the warming influence of the carbonic acid must be greater than according to Table II., which was calculated by means of Glaisher's values. This conclusion, of course, holds good only for those parts of the earth and for those seasons in which the decrease of temperature with the height is as great as the above-named French and German observations indicate. I shall now consider this point more in detail.

Our knowledge of the variation of the temperature of the atmosphere with the height above sea-level is very imperfect indeed. Especially we know very little about that variation in the Arctic Regions and at the great centres of cold in the northern continents during winter. There the mean temperature of the lowest layers of the air generally sinks below - 40° C. and a temperature of - 50° or - 60° C. seems not

to be rare. A minimum of $-50°$ C. has been observed in the centre of cold in North Scandinavia.[1] Nansen observed a minimum of $-52°·6$ C. during the voyage with the *Fram*, and at Werchojansk in Siberia the absolute minimum hitherto observed is $-69°·8$ C. There are, however, strong reasons to believe that the temperature of the air in the layers above these centres of cold is higher than in those nearer to the earth's surface. Thus, for instance, the Swedish geologists, especially Axel Hamberg, have placed minimum thermometers on mountain tops in Lapland (North Sweden). Hamberg[2] found in 2100 metres above sea-level an absolute minimum of not more than $-27°·8$ C., and a comparison with the minima at adjacent low stations (200 to 300 metres above sea-level) gave the result that the minimum at the top was about 10° C. higher than it was at the low stations. The meteorological observations arranged by J. Hann and others in the Alps have given a similar result. Also a consideration of the general state of the weather during the periods of such extreme cold leads to the conclusion that in those regions the temperature at a higher level is higher than near the ground. For when the weather is anticyclonic the air is slowly sinking down over those regions, and thereby dynamically heated. But near the ground the air cooled by radiation is nearly stagnant and in very stable equilibrium, so that the warmer air in the higher levels is probably flowing over it outwards from the centre of the anticyclone without reaching the ground. Thus over those cooled regions there is, probably to a considerable height, an increase of temperature with the height, and this is called temperature inversion.

As now in those centres of cold the warming influence of the insolation is very feeble or zero (as such weather occurs in the winter in high latitudes), and as the air circulation is such as to prevent all heating by means of air currents coming from warmer regions, the only source of heat is the feeble radiation from the upper dynamically heated air. Simultaneously the radiation from earth into space is relatively unimpeded, the sky over an anticyclone being relatively clear. Thus the severe cold is explained, and it will be obvious that the protecting influence of the carbonic acid is very much enfeebled by those circumstances, so much the more so as the quantity of water vapour is insignificant, partly owing to the low temperature, partly on account of the downward movement of the upper air. Also the snow covering of the ground is very favourable for the development and permanence of such a state of weather, for the snow radiates heat as a black body, and being a very bad conductor of heat, completely hinders the supply of heat from the ground; also the evaporation from the cooled snow surface is nearly insensible, and often the snow, instead of evaporating, condenses the aqueous vapour in the air on its surface.

By comparing this state of weather with the general state according to the description given above (p. 20), we see that it is, up to a considerable height above sea-level, the complete inversion of the general

[1] About 69° N. and 25° E. from Greenwich. As to the state of temperature of the Scandinavian Peninsula, I refer to my paper on this matter in *Ymer*, 1899, p. 221 and following, with 6 charts.

[2] Axel Hamberg, *Ymer*, journal edited by the Swedish Society for Anthropology and Geography, Stockholm, 1899, p. 463 (Swedish).

state, the temperature increasing upwards from the ground instead of decreasing. How great this height is we do not yet know, but evidently it is more than 2000 metres in Lapland, and perhaps the radiating layer, the mean height of which in this case is about 15,000 metres, is not colder than the ground. This circumstance explains in full the incompetence of the carbonic acid to protect the ground from being cooled by radiation to a very low temperature in this instance. But if the quantity of carbonic acid were sufficiently increased, it would be able to prevent in most cases the formation of those winter anticyclones generated nowadays over certain arctic and northern regions. Instead of the anticyclonic winter cold, we should then have there a prevailing cyclonic weather—equal to the present common winter weather on the western coast of Europe. The winds would constantly transport warmer air from more southerly districts to the Arctic Regions; the sky would be cloudy, thus effectively hindering the radiation into space; and no noticeable inversion of temperature would occur. Under these circumstances then the protecting influence of the carbonic acid would act with its full power, and we should have a mild winter climate even in the Arctic Regions.

An interesting circumstance is here to be borne in mind. As long as the protecting power of the carbonic acid is strong enough to prevent the formation of the anticyclonic weather generated by a permanent cooling of the ground over large districts and the temperature inversion in the lower atmospheric strata resulting from it, the protecting influence of the carbonic acid will be greatest in the regions, daytimes, and seasons which are least favoured by nature; thus greatest at the pole, and from it decreasing towards the equator, greater during winter and night than during summer and day. Briefly, a sufficient quantity of carbonic acid will produce not only a warm climate, but also a uniform one over the whole earth. An inverse action will, of course, be produced by want of carbonic acid; thus not only a general fall of temperature, but also strong climatic contrasts between the different climatic zones and seasons.

The opinion that the genial climate of older geological ages was due to a greater quantity of carbonic acid in the atmosphere than the present one is by no means new. On the contrary, it was common among older geologists. But as the opinion then still was in want of support from physical facts, it was but an unproved conjecture. And as so enormously great a protecting power of the carbonic acid as we have found it to be was not suspected, it was thought necessary to assume a very high rate of carbonic acid in the atmosphere of ancient times in order to explain its genial and uniform climate. But as such a rate would have been fatal to all higher animal life, that objection was fatal to the hypothesis.[1] Further, those elder geologists believed it to be necessary for their explanation also to assume that the sky of those ancient times was much more cloudy than the present one, and besides that the inner heat of the earth contributed to the high temperature of the atmosphere. The last supposition is, as shown above, quite untenable.

[1] Eug. Dubois, *l.c.* p. 166, tells us positively: "The supposition of a formerly greater amount of carbonic acid in the atmosphere can now no longer be seriously discussed"; and this statement is considered to need no proof (!).

As to the question about cloudiness during different geological ages, there is no reason at all to believe that the sky of the genial periods was on an average more cloudy than the present one, but rather the contrary. For the more cloudy the sky is, the lower is generally the mean temperature of the air. Also the meteorological observations show that the amount of clouds on the whole increases from the equator to the pole, and does so though the rainfall decreases. But the amount of clouds has also a daily and a yearly period which play a very great part for the temperature. As a rule, the sky during the day is a little more cloudy than during the night, which, of course, enfeebles the insolation and reinforces the nocturnal radiation, thus lowering the temperature. The same may generally have been the case in the climates of ancient times. But as for the yearly period of cloudiness, the state is more variable. The climate of Western and North-Western Europe is characterised by the fact that the sky is much more cloudy during winter than during summer, and this is a cause which acts powerfully in producing the favourable climate of this region with its sufficient summer heat and moderate winter cold. But there are other regions on the earth where the inverse state prevails; the winter sky being as a rule rather unclouded, whereas a covered sky and frequent fogs characterise the summer weather. This is particularly the case in the polar regions, where the cold sea, filled with melting ice, seems to be the cause of the foggy and cloudy weather during the middle summer season. Again, there are other regions where the winter sky is nearly continually clear, and as a consequence the winter cold severe, but also the summer sky generally so cloudless that the insolation suffices to produce summer heat. This is the case in the interior of the great continents even north of the Arctic Circle.

Now, if we ask what was the yearly period of the cloudiness in the Arctic Regions during the Cretaceous age, when a nearly tropical climate prevailed there, the answer will be that probably the period was such as it is in Western Europe nowadays, *i.e.* that the summer sky was relatively cloudless and the winter sky relatively cloudy. For there can be no doubt that the polar regions were then washed by a lukewarm sea completely free from ice, just as now the Iberian Peninsula, France, and the British Isles. We may thus with a great probability assume that the beneficial climatic influence of the carbonic acid for the polar regions will be extraordinarily increased as soon as the quantity of it in the atmosphere has become great enough to prevent the formation of ice on the polar sea during the winter. If we imagine of what kind the polar night would be on an island which, like Ireland, was situated in the middle of a lukewarm sea and under a sky mostly covered, we cannot doubt that even with the present rate of carbonic acid in the atmosphere such an island would have a relatively high winter temperature. Even in Spitzbergen, which has a relatively clear winter sky and is surrounded by a sea partly covered with ice, the midwinter temperature is at present, owing to the influence of the warm Atlantic continuations of the Gulf Stream, higher than in the northern centre of cold of the Scandinavian Peninsula.[1] If the hypothetical polar island,

[1] According to my isothermal chart of Europe (*Ymer*, 1899, *l.c.*) the mean January temperature reduced to sea-level is − 16° C. in this centre (about 69° N. and 25° E. fr. Gr.),

moreover, had to enjoy a summer sun shining nearly continually during half the year from a relatively cloudless sky, it would probably have a summer heat fully comparable with that of Southern or Central Europe. Considering all this it will seem very probable that the influence of a variation of the quantity of carbonic acid in the air will be at least twice as great as according to Table II. for the Arctic Regions and higher latitudes, where now during the winter temperature inversions are common. Thus a diminution of the carbonic acid to two-thirds of its present amount will probably lower the mean temperature of the northern regions by at least 5° C., and hence produce the climate of the Great Ice Age.[1] Likewise an increase of carbonic acid to triple its present amount would probably produce a rise of the temperature amounting to 18° or 20° C., and thus restore to those ice deserts the rich and flourishing nearly tropical flora which was to be found there during the Cretaceous period. Also the temperate polar climate of the Miocene age, with its slowly proceeding deterioration, may have occurred during a rate of carbonic acid not much greater perhaps than the present one, the cooling influence of a slow decrease of carbonic acid exhibiting its full strength only much later.

All these consequences drawn from Arrhenius's theory compared with the present climatic conditions agree, as one may see, perfectly with the testimony of geological facts. Before the theory can be considered as proved, we must, however, examine if it is probable that the quantity of carbonic acid in the atmosphere has really undergone such secular variations, and by what they have been caused.

The present quantity of carbonic acid in the atmosphere is, as we know, very insignificant, viz. only $\frac{45}{100000}$ of the whole mass of the air. Compared with it the quantities produced and consumed in a single year are not quite unimportant, as was shown particularly by Högbom.[2] Thus he finds that the present combustion of coal generates in a year as much as one-thousandth of the total amount of carbonic acid in the atmosphere. Carbonic acid is consumed in nature by chemical processes, especially by weathering of silicates and by the vegetable processes of plants. New carbonic acid is brought to the atmosphere principally by volcanic forces,[3] and also by shooting stars and meteorites, which are burnt in the uppermost layers of the atmosphere. Combustion and rotting of the actual vegetation only give back to the atmosphere what this vegetation had taken from it some years ago. The same

whereas the mean January temperature at Spitzbergen (about 79° N. and 16° E. fr. Gr.) is −11°·4 C. according to the observations made by the Swedish Expeditions of 1872-73 and 1882-83, and −14°·1 C. according to the calculation of J. Hann, *Met. Zeitschr.*, 1894, p. 46, and *Handbuch der Klimatologie*, Zweite Auff., 3 Bd., p. 504, Stuttgart, 1897. The January temperature for this latitude of Spitzbergen given in A. Buchan's charts is much too low, viz. −12° Fahr., or −24°·4 C. (*Challenger Expedition—Physics and Chemistry*, vol. ii. London, 1889; and Bartholomew's *Physical Atlas*, vol. iii., Westminster, 1899).

[1] By inspection of the temperature charts of Scandinavia published in my above-cited paper, it will be immediately clear that the glaciation of Europe must have begun at the two centres of cold appearing every winter in our Peninsula.

[2] A. G. Högbom, *Svensk kemisk tidskrift*, Bd. 6, p. 169, 1894 (Swedish chemical journal).

[3] V. Uhlig and M. Neumayer, *l.c.* p. 89, tell us: "Die aus einem Bohrloch bei Neusalzwerk strömende Quelle liefert jährlich etwa 140,000 Kilogramm Kohlensäure"; see also J. C. Chamberlin, "The Influence of Great Epochs of Limestone Formation upon the Constitution of the Atmosphere," *Journal of Geology*, vol. vi. p. 611, Chicago, 1898.

holds good for the carbonic acid which animals exhale or which is formed by the putrefaction of bodies of animals; for this comes, without exception, from the plants which have served as food for the animals.

What enormous quantities of carbonic acid passed through the atmosphere during ancient times is best shown by the thick layers of limestone and chalk which are to be found in several geological formations, and which contain many thousand times as much carbonic acid as the present store of the atmosphere.[1] The quantities of carbon which are stored up as pit-coal, brown-coal, and turf mosses are certainly not so great, but nevertheless are gigantic.

We may thus say that the carbonic acid trade of nature is carried on with a very little capital and a very great exchange, in which, moreover, chance plays a considerable part. Hence it follows necessarily that great fluctuations in the capital stock will occur, so that sometimes abundance and sometimes want arises in the carbonic acid market. And if a reserve fund did not exist, it is to be feared that severe crises would occur now and then, which, from abundance or want of carbonic acid, and hence of heat, might be fatal to all life on the earth. This reserve fund lies in the carbonic acid stored up in the oceans. For sea water is capable of storing up a great amount of carbonic acid partly as a solution and partly as a loose chemical combination in the bicarbonates.[2] Arrhenius calculates that if six parts of carbonic acid be supplied to the air, five of them will go down in the ocean and only one remain in the air. Chamberlin takes into consideration a further circumstance of great importance, viz. the activity of limestone-secreting organisms. According to him, the total store of carbonic acid existing in the ocean in solution and in a loose chemical combination amounts to eighteen times as much as that in the atmosphere; by the activity of the limestone-secreting organisms, the loosely combined carbonic acid is set free and is partly given back to the atmosphere. Consequently if during a period of unusually lively volcanic activity on the earth the atmosphere receives a great supply of carbonic acid, most of it is stored up in the ocean—in part directly by absorption, in part indirectly by the weathered detritus transported by the rivers to the ocean. Out of this stored provision a part is gradually precipitated in form of calcium carbonate, but the rest is gradually given back to the air, especially if the quantity of carbonic acid in the atmosphere is diminished.

5. *The secular cooling of the earth is the principal cause of the variation of the quantity of carbonic acid in the atmosphere—Modifying influences.*

The principal cause of the secular or long-period variations of the quantity of carbonic acid in the atmosphere is to be found in the secular cooling of the earth, as will now be shown.

[1] A. G. Högbom, *l.c.*, calculates the store of carbonic acid in the stratified rocks to be 25,000 times that in the air, assuming the mean thickness of these strata to be 100 metres over the whole surface of the earth, which is probably a minimum value.

[2] S. Arrhenius, *Nordisk Tidskrift*, 1896, pp. 129-130; and J. C. Chamberlin, *l.c.* p. 611 and following.

We have already shown[1] that during the primeval time, when the whole crust was covered by the ocean, the crust contracted more than the inner nucleus, and that thereby a lively volcanic activity was produced—a state which probably continued many million years during the Pre-cambrian time. Further, we explained there how gradually an inverse state arose, during which the nucleus contracted relatively to the crust so as to form crumples on the crust, and this was the beginning of the first great mountains and continents. The explanation, however, there given of the formation of mountains and continents was incomplete; for we must consider one more important circumstance, viz. the influence of the carbonic acid on the temperature of the ocean and the air. For as the volcanic activity during the primeval time, as long as the crust contracted more than the nucleus, was singularly strong, the supply of carbonic acid to the ocean and the air was considerable. And as nearly all the ground was covered by sea, and the vegetable life but

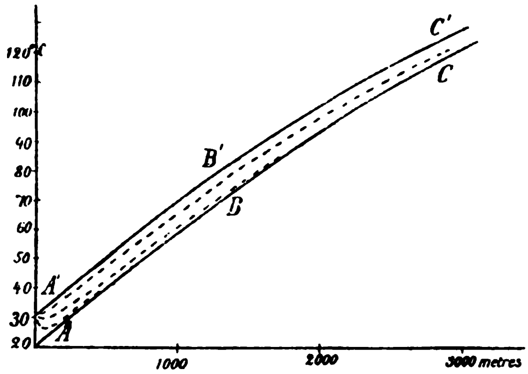

FIG. 1.

little developed, the consumption of carbonic acid by weathering of silicates and by organic processes was insignificant. Accordingly, the quantity of carbonic acid increased continually, and, by consequence, the temperature of the air, then that of the ocean, and further that of the ground and of the sea bottom, gradually rose. And if simultaneously also the intensity of the insolation increased, which is not improbable,[2] that rise of temperature was still greater. We shall now see what was the influence of this on the crust. Suppose, for instance, that the mean temperature of the ground (= sea bottom) was 20° C. during the primeval time, but gradually rose to 30° C.[3] Fig. 1 gives a graphic representation of the increase of the temperature in the earth with depth. According to the known laws of the conduction of heat, the temperature at different depths is represented by the faintly bent curve ABC, as long as the temperature remains constant at 20° C.[4] But if the mean temperature of the air is raised to 30° C. and main-

[1] Chapter 1, pp. 5 and 6.

[2] Cp. chapter 3, p. 17.

[3] We have already seen that a relatively little increase of the quantity of carbonic acid in the atmosphere is sufficient to produce an increase of temperature equal to 10° C.

[4] The yearly and other variations of short period do not sensibly alter the regular course of the curve, for they penetrate only to a depth of a few metres.

tained at this degree during millions of years, then firstly the ocean is warmed, secondly heat penetrates from it and from the air into the earth's crust, and simultaneously the conduction of heat from the interior of the earth is going on invariably in the deeper layers. At first the temperature is speedily raised in the uppermost layers owing to the supply of heat from above (the dotted lines are intended to indicate this), then a very slow rise of temperature is going on, owing to the supply of heat from below, and this extends to depths which are always increasing, until the curve A′B′C′, representing the new distribution of temperature, has become nearly parallel to the former curve ABC, but at a depth of several kilometres.[1] Consequently then the temperature of the crust has been raised relatively to the nucleus by about 10° C. What this signifies is shown by a simple calculation. The coefficient of linear thermal expansion of the crust may be assumed to be 0·00002 per 1° centigrade; and as the circumference of the earth is 40,000 kilometres, the whole circumference is lengthened by $10 \times 0{\cdot}00002 \times 40{,}000 = 8$ kilometres. But as the crust is not strong enough to break loose from the nucleus, it must bend and crumple itself in order to find room. If only one fold were formed at the end of the period of expansion, it would have a height of nearly four kilometres, which would be as high as the tops of the Alps. To this comes, moreover, the surplus already pointed out depending on the slow cooling of the nucleus. Moreover, as is proved by the geological facts, the effect of such a slow expansion is in reality enormously greater than the above calculation seems to indicate. For as soon as the expansion of the crust has been great enough to produce a crumple in it, this generally splits and the fissures formed are filled with eruptive magma, which is pressed up as wedges. Also the cavity formed under the crest of the crumple will be filled with such a magma. Thereby the crust will increase still more in length, thickness, and rigidity, whereas the nucleus will diminish in volume, so much the more as a part of the magma will often rise and spread over the surface of the crust. After some time a new crumple will be formed, and the same process will be repeated, and so on. Thus the above result found by Hein (see p. 8) ought to be explained.

In this manner the first great mountains and continents rose from the ocean. But as the chemical processes by which carbonic acid is consumed, both in inorganic and in organic nature, are strongly accelerated by a high temperature and also directly by an increase of carbonic acid, and as the land areas where these processes were going

[1] The depth at which the amplitude of a periodical variation of the surface temperature is reduced in a given rate being proportional to the square root of the length of the period, and the amplitude of the yearly period being reduced to the half at a depth of 2 to 4 metres (varying with the conductivity of the ground), we find the following lengths of the period corresponding to depths, at which the amplitude is reduced to the half of its value at the surface:—

Length of period.	Depth in metres.
1 million years	2000 to 4000
4 " "	4000 to 8000
9 " "	6000 to 12000
16 " "	8000 to 16000

a. s. o.

A. J. Ångström, "Mémoire sur la température de la terre à différentes profondeurs à Upsal, Upsal, 1851," *Acta Reg. Soc. Sc. Upsaliensis*, Sér. 3, vol. i. pp. 147-224, Upsaliæ, 1855.

on had a very great extension compared with that of the former age, the consumption of carbonic acid was now increased to so high a degree that the quantity of it contained in the air became at first stationary and then began slowly to diminish. But during long times this diminution was prevented by the influence of the oceans. For by the denudation and erosion of water a great many carbonates, etc., were transported to the oceans, which thereby provided a richer food than before to the lime-shell animals. By the vital processes of these animals great quantities of carbonic acid were gradually set free and given back to the atmosphere as explained above, according to the theory of Chamberlin. Hence the temperature of the genial period was still raised and its duration lengthened. But as the ocean gives back to the atmosphere only a part of the carbonic acid consumed by the chemical processes, whilst the rest is precipitated in the form of stratified layers of limestone, a time must have come when the provision stored

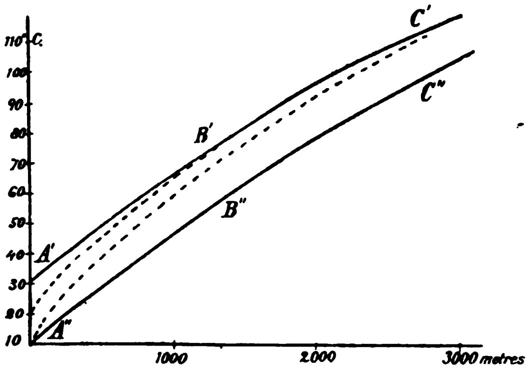

Fig. 2.

up in the ocean was consumed, and then the quantity of carbonic acid in the air gradually diminished. By consequence, also, the temperature of the air became first constant and then began slowly to fall. As a consequence, the cooling and contracting of the earth were going on, during a long time, at the same rate both in the crust and the nucleus. Thus a state of rest arose in the volcanic activity, and accordingly in the production of carbonic acid, and the temperature fell more and more and the climate deteriorated.

But the relatively low temperature which now ruled during long ages exercised two influences which gradually increased the rate of carbonic acid again, and thereby raised the temperature of the air, ocean, and ground.

Firstly, the consumption of carbonic acid for weathering silicates and for other chemical processes, both in inorganic and organic nature, was considerably diminished owing to the low temperature.

Secondly, the volcanic activity was increased, which caused an increased production of carbonic acid. In order to understand this, let us consider Fig. 2 (cf. Fig. 1), and suppose that the mean temperature has

fallen from 30° to 20°, and then further from that to 10° C.[1] Now let the curve A′B′C′ represent the distribution of the temperature at different depths towards the end of the genial period, when the mean temperature of the earth's surface was still 30° C. As soon as this has fallen to 20° C., the heat of the crust is rapidly going away from the uppermost layers to the surface and radiating away from it. Thereby the geothermal gradient is gradually increased, and, of course, also the loss of heat by conduction; and this will go on to continually deeper layers, until the distribution of temperature will be such as that indicated by the dotted line beginning at 20° C. at the surface. Further, as soon as the mean temperature of the surface has fallen to 10° C., the heat is conducted still faster away from the crust, and the distribution of the temperature after some time will be that indicated by the dotted line beginning at 10° C. in the surface. If this low temperature continues long enough, the heat of the earth is carried off from always deeper layers, and finally the distribution of the temperature will be that indicated by the curve A″B″C″, which, still at a depth of several kilometres, is running nearly parallel to A′B′C′. Thus the mean temperature of the crust has fallen by not less than 20° C. in a relatively short geological period. In the same time the nucleus has been cooled only very little, at the most 1° or 2° C., and thus, principally owing to the diminution of the quantity of carbonic acid in the atmosphere, a relative fall of temperature amounting to nearly 20° C. has taken place in the crust. A contraction is thereby produced in this relatively to the nucleus, the amount of which may be easily calculated if we know the coefficients of thermal linear expansion for the crust and for the nucleus. For the former we assume, as above, this coefficient to be 0·00002, for the latter we may suppose it to be twice as great, or 0·00004, and accordingly the relative contraction of the crust will be at least $20 \times 0{\cdot}00002 \times 40{,}000 - 2 \times 0{\cdot}00004 \times 40{,}000 = 12{\cdot}8$ kilometres on the whole circumference of the earth. Evidently, as long as this contraction is going on, a great many fissures and subsidences in the regions formerly crumpled, with accompanying volcanic eruptions, will occur. But thereby a genial geological period is again inaugurated. This, of course, just as the former periods, will then have its progress, culmination, and decadence, owing to the repetition in nature of nearly the same influences as before, and this will go on as long as the interior of the earth is hot enough to maintain volcanic activity.

Thus during the whole geological interval a periodical variation in the mean temperature of the atmosphere, the ocean, and the upper crust of the earth has been going on, as shown by the above reasoning, which is based exclusively on physical arguments. It is evident that the length of such a period will be considerable, and will probably amount to many million years; but this theory, of course, is unable to determine its mean length.

It now remains also to prove the existence of this variation by means of purely geological facts; but before doing this we shall consider two more physical circumstances which will noticeably modify the variation.

[1] This is not more than the probable fall of temperature from the Cretaceous to the Pleistocene period.

The one is the continual erosion and denudation of the continents by means of rain. Its effect will be very complicated; for on the one hand it uncovers the rocks for the weathering process and thus reinforces the consumption of carbonic acid, but on the other hand it transfers, directly or indirectly, the surface of the earth to the sea, where it is covered by water and thus protected from weathering. Probably the latter effect is stronger, and thus, the weathering being much more active during the warm periods than during the cold ones, the result will be that the warm periods are much strengthened and lengthened and the cold ones enfeebled and shortened. Also the erosion and denudation is very important for life on land and in sea, and thereby may exercise a marked influence of a very complicated nature. I cannot enter on this question, which has been elaborately discussed by Chamberlin.[1]

The other modifying circumstance is the influence of the great oceans on the temperature on the earth's surface.

As we know, the ocean, nowadays, covers the greater part of the earth's surface, and there can be no doubt that this has always been so. But out of the heat that the ocean receives from the sun and the air, only a little part penetrates to its bottom. For as a rule the heated water is more buoyant than the underlying colder layers, and thus is floating above. Only exceptionally does it happen that the warmer water sinks down owing to its greater saltness. The slow motions in the oceans caused by the differences of temperature are at present such that the ice-cold water at the poles is sinking down, and spreads on the bottom of all deep seas which communicate with the polar basins. Owing to this, the temperature of the sea bottom is at present nearly constant, and about the freezing-point or a little below. This has evidently been so since the Great Ice Age. The rise of the mean temperature of the air, amounting to about 5° C., which has taken place since the Ice Age, has thus only come to benefit the crust in a small degree.

Something similar must also hold good for earlier geological ages. For even during the periods when the polar regions enjoyed a temperate or genial climate, the mean temperature there must nevertheless have been lower than nearer to the equator, though the difference ought then to have been less than during the colder periods. And if the deep oceans always have communicated at least with one of the polar basins, —which I believe was the case,—we must conclude, according to the laws of physics, that the mean temperature of the bottom of the ocean has always depended on the temperature of the surface of the polar basins, where the coldest water sank to the bottom.

Hence it can only have been during the hottest periods of all that the expansion of the crust, owing to heating from above, became so considerable that great mountains and continents were lifted up from the ocean. Furthermore, it is evident that the calottes of the crust which surround the poles ought to have got, on account of the stronger cooling, a greater rigidity than the other parts of the crust, where the cooling will, on the whole, have been feebler. In consequence, the polar calottes have been less crumpled than the other parts of the crust, and no large

[1] T. C. Chamberlin, *l.c.* p. 616 and following.

and mountainous polar continent has probably ever existed, unless, perhaps, during the primeval or Archæan era.[1]

It also follows from the above that an increase of the mean temperature of the atmosphere is only slowly and partly communicated to the bottom of the ocean, and from hence to the crust, whereas a decrease is rapidly and in an exaggerated scale propagated to it. Now we have seen that every heating of the crust produces effects that tend to increase the consumption of carbonic acid, and accordingly to cool the atmosphere. Thus the ocean, by protecting the crust from being heated from above, has the effect of prolonging an age of genial climate. On the other hand, as every cooling of the crust produces effects that tend to rapidly augment the production of carbonic acid and thereby to warm the atmosphere, it results that the ocean, by accelerating the cooling of the crust by means of ice-cold water, has also the effect of shortening considerably the length of a cold geological period. Thus we are led to the conclusion that the geological periods of an intense cold have constituted only a very short time in comparison with the periods of a genial climate.

We will now compare the above theory with the testimony of geological facts.

First, then, I shall remark that the explanation given above of the principal cause of volcanic activity and formation of mountains and continents fully agrees with the views of modern geologists, as far as I have been able to judge.[2] And I think that some of the difficulties hitherto felt in the explanations of the facts observed will be removed by applying the above theory to these facts.

Firstly, the geological history of the earth gives evident proofs that both the volcanic activity, the formation of continents and mountain ranges, and the climate during the geological past have undergone such a periodical variation as I have deduced from a purely physical reasoning. And these proofs are more evident the more fully we know the geological facts.[3]

Of what has passed on the earth during the Archæan era and the older periods of the Palæozoic era we know too little to be able to make a comparison. We can only say that there is nothing to be found in the facts now known that disproves our theory.

But after that time there are positive facts enabling us to make a comparison. Thus, according to Frech,[4] we may distinguish during the history of the earth two periods during which a mountain formation embracing the whole globe has occurred, viz. the younger Palæozoic (Carboniferous) and the second half of the Cainozoic era (after the Oligocene),

[1] If the angular velocity of the earth in its rotation has been noticeably retarded by tidal friction, and as a consequence of it the earth has gradually taken a more spherical form during geological time,—which is very probable,—the same effect will have been produced thereby, viz. the crumplings of the crust accompanied by fissures nearer the equator, and the forming of fissures without crumpling in the vicinity of the poles.

[2] See, for instance, the treatise by Neumayer and Uhlig cited above.

[3] Sir Archibald Geikie, *Text-Book of Geology*, 2nd ed., London, 1885, p. 22, says: "As evidence has accumulated in favour of periodic alternations of climate, the conviction has been strengthened that no mere local changes could have sufficed, but that secular variations in climate must be assigned to some general and probably recurring cause." (The last edition was not accessible to me.)

[4] Fritz Frech, "Ueber die Gebirgsbildung im paläozoischen Zeitalter," *Geographische Zeitschrift*, Jahrg. V. 1899, p. 563 and following.

whereas the Mesozoic and the beginning of the Cainozoic era were generally times of deep immobility. According to Neumayer and Uhlig,[1] we may likewise distinguish a Pre-permian and a Tertiary period of general activity of mountain formation, which are separated by a long period of rest, during which no crumplings and only few volcanic eruptions occurred, whereas the immersion of land in the ocean increased, and stratified deposits were continually formed. But these authors put the beginning of the later period of activity somewhat earlier than Frech, viz. in the upper Cretaceous, though the principal crumpling occurred later, and was going on with interruptions till the Pliocene.

Now both these active periods constitute the later part of a very warm period, and the transition from it to a very cold one. During the warm period we find a luxuriant vegetation, during the cold one a poor vegetation and a glaciation of large regions of the ground. As to the elder of these periods, the Permo-Carboniferous, the facts are less reliable; but, according to the opinion of most geologists, it ended with a cold age, which approximately falls in with the Permian period. The rich flora of the Carboniferous period was then partly extinct, and a check in the vegetation occurred. Also a glaciation of large regions, comparable with that following the Tertiary period, occurred. The traces of this glaciation have been found principally in the southern hemisphere, where a great continent existed at that time, and may be partly explained by the height of the land. But its existence and great extension seem to be acknowledged as a fact by nearly all geologists. But it did not last long, geologically speaking; for after it occurred the Mesozoic era, which seems to have enjoyed an invariably genial climate. This long warm age culminated during the Cretaceous and Eocene periods, when the vegetation again reached a luxuriance comparable with that of the Carboniferous era. But then a great activity in the formation of mountains and continents set in, and as a consequence we see a gradual deterioration of the climate, commencing just as after the culmination of the Carboniferous warmth. The temperature is now falling rapidly,—geologically speaking,—and at last the Great Ice Age breaks in. As to this, there is no doubt about its existence and extension. For it has left traces all over the globe, and they prove that the lowering of the temperature was general. The snow-line is found to have been lowered everywhere on the earth by about 1000 metres, indicating a temperature about 4° or 5° C. lower than the present one. But the cold period was but short compared with the enormously long genial age previous to it. And the cold was not continual. For it was interrupted by at least two or three temperate inter-glacial ages, during which the climate was even somewhat milder than at present. Some geologists count up to six inter-glacial periods. Some of these may have been only local, consisting in a melting away of the southern borders of the ice by a rise of the summer temperature owing to the astronomical cause considered in the next chapter. But the great and general inter-glacial periods of the Pleistocene cannot be explained thus. They no doubt depend on the same cause as the long-period changes above discussed—that is to say, on a variation in the quantity of carbonic acid of the atmosphere. I shall now show that these periodical variations during the Pleistocene were

[1] Neumayer and Uhlig, *l.c.* p. 357 and following.

probably caused by the modifying influences pointed out above, viz. the erosion and denudation of the land by water and ice, and the influence of the ocean on the temperature of the upper crust. Of these two influences, the latter was no doubt the far more effective, and therefore we shall consider it first.

During the hottest period, Cretaceous and elder Cainozoic, the crust was heated, and thus expanded relatively to the nucleus. But the heating and expansion were by no means uniform, for the continents were heated much more than the sea bottom. Moreover, this had generally a greater rigidity than the land, as it had been cooled by the water. The consequence was that the crust was crumpled principally along the coasts[1] and in the warmer regions of the earth. Very instructive in this respect is the account which Suess gives of the extension of the young mountain ranges. We see from it how the wrinkle caused by the relative expansion of the crust runs from the south-west point of Europe eastward over the south of Asia to the East Indian Islands, then north-eastward along the east coast of Asia up to Kamtschatka, and from that turns in a sweep southwards over to North America and farther along the west coast of this continent, whence it turns in another sweep to the east over the West Indian Islands to the north end of South America, and finally along the west coast of it down to Cape Horn and perhaps on as far as Graham Land. Thus we see that the crust has closed up both in a north-southerly and east-westerly direction, but principally in the warmer regions of the earth by means of a crumple running along the coasts.

Now as soon as the temperature had fallen enough to produce a glaciation of the polar regions, the sea bottom was rapidly cooled by ice-cold water, whereas the continents at a greater distance from the poles were still relatively warm. In consequence, the sea bottom contracted, and the fissures at the borders of the young mountain ranges along the coasts were opened so as to produce vertical faults with subsidence of large regions along the feet of the mountain ranges. Thereby arose a very lively volcanic activity, producing a range of volcanoes and volcanic eruptions along the new mountain range, and also in several other places. This is shown very strikingly by the chart given by Neumayer and Uhlig.[2] This volcanic activity is said to have been very lively during the whole Pleistocene period, and there can be no doubt that it culminated during the periods of glaciation. Thereby was produced a great quantity of carbonic acid, and at the same time the consumption of it was considerably diminished, owing to the low temperature and the ice-covering of large regions. By consequence, the quantity of carbonic acid increased, and a temporary amelioration of the climate occurred, forming an inter-glacial period. This process may have been repeated several times.

During the inter-glacial periods, the upper crust of the land was somewhat heated, but their length was probably too short to produce an expansion sufficient for mountain formation, so much the more so

[1] Thereby I do not mean to say that a crumpling along the coasts is a general rule in the formation of mountains, but only that it probably is more common than the crumpling of the crust far from the coasts.

[2] Neumayer and Uhlig, *l.c.* p. 194, "Vertheilung der Vulkane auf der Erde."

as the temperature of the sea bottom remained constant at about the freezing-point during the whole Pleistocene era, and from that to the present time.

But during all this time erosion and denudation acted constantly to diminish the large surfaces of the mountains and continents formed during the end of the warm period. Simultaneously also large land areas were immersed under water, such as the Mediterranean, the Red Sea, the greatest part of Scandinavia and Finland, the regions south-east and east from Asia, the Caribbean Sea, etc. Thus, after some glaciations the consumption of carbonic acid must diminish so much that a permanent or at least very long amelioration must occur. But the end of the last glaciation occurred so recently that we cannot say if we now are living in an age of periodical glaciation or at the beginning of a genial period.

6. *Variations of the obliquity of the ecliptic, and their influence on the climate.*

After we have thus tried to explain the cause of the great climatic changes during the geological past, it remains to examine the smaller ones. Among these there is one that requires our special attention, because it very nearly concerns us. It is a climatic variation which has been shown to have happened during the Quaternary time, after the melting away of the ice in the northern countries, particularly in Scandinavia, Spitzbergen, and Greenland, and which no doubt is still passing on. It has been also, if not discovered, yet examined most accurately by Swedish botanists and geologists—F. W. C. Areschoug, S. Berggren, Th. Fries, A. G. Nathorst, Gunnar Andersson, H. Hedström, and others.

Already Berggren and Fries, but still more positively Nathorst,[1] conclude, from the phyto-geographical state of Spitzbergen, that there must once have been a time, after the present vegetation of Spitzbergen already had immigrated, or during which it was immigrating, when the climate was warmer than now. And proofs of the existence of such an age is also afforded by the geological evidence, which shows that there was an interval during the post-glacial period when the sea was warmer than at present, so that *Fucodium canaliculatum*, *Mytilus edulis*, *Cyprina islandica*, and *Litorina litorea* could live there, none of which nowadays is to be found in the Spitzbergen waters. Further, Nathorst remarks that signs of a milder climate during the post-glacial time may be found over nearly all the northern parts of our hemisphere—Scandinavia, Iceland, Greenland, North America, etc. This was indeed indicated already in 1866 by Areschoug concerning Scandinavia, for the reason that certain plants, as *Trapa natans*, *Ilex*, *Acer campestre*, etc., had formerly wider northward dissemination than now. Also British authorities, as J. Geikie and J. D. Hooker, have arrived at the same result. So far

[1] A. G. Nathorst, "Nya bidrag till kännedomen om Spetsbergens kärlväxter och dess växtgeografiska förhållanden" ("New Contributions to the Knowledge of the Vascular Plants of Spitzbergen and its Phyto-Geographical State"), Stockholm, 1883, *K. Sv. Vet. Ak. Handl.* Bd. 20, No. 6, p. 63 and following pages.

Nathorst. It may be remarked that already Ehrenheim,[1] in 1824, tells us, as a proof of the deterioration of the climate in later times, that wood formerly grew in the northernmost part of Norway long above the present wood limit.

Gunnar Andersson,[2] on the basis of the history of the Swedish vegetation, has given a general description of what is at present known about the climate of Sweden during the Quaternary Age. Later he has in the same way studied the climate of Finland also. After the melting away of the ice the temperature gradually rose, and a steadily increasing flora immigrated. First came an arctic vegetation, the Dryas flora, with Dryas, arctic willow, and dwarf birch; later came the flora of the common birch, then that of the fir, and at last that of the oak. The latest indicates the warmest time of the Quaternary climate. The oak grew then farther to the north than now, and formed real forests as well in Southern and Middle Sweden as in Southern Finland, and the hazel (*Corylus avellana*) throve in Southern Norrland north of the 63rd latitude.[3] Simultaneously the water-calthrop (*Trapa natans*) throve and ripened its fruit in the lakes of Southern and Middle Sweden and Southern Finland. Andersson has also tried to determine approximately the millenary of our era, when this warm climate occurred. The oldest known traces of the existence of man within the limits of Scandinavia first inhabited descend to the middle or later part of the Oak Age, and these men belonged to the elder Neolithic Stone Age, who did not know the use of sharpened flint. Now as, according to Oscar Montelius, the Bronze Age of Sweden began at latest about 1700 years B.C., and Andersson estimates the duration of the Stone Age in our country as at least equally as long time as that which has elapsed from the beginning of the Bronze Age to our time, and perhaps some one or more thousand years longer, thus man has lived in Sweden for at least 7000 years, and perhaps some one or more thousand years longer. The time of the warmest climate in the northern countries accordingly occurred some 10,000 to 7000 years ago. But after that time the climate has again gradually deteriorated, and, as we shall see, the deterioration is still going on. The water-calthrop, for want of summer heat, has become completely extinct in Finland and also in Sweden, and is now to be found only in a single lake in Scania; this plant is said now to thrive well only in South Europe. The oak, hazel, etc., have retired backwards to the south, partly for want of summer heat, partly owing to the struggle with other trees and shrubs requiring less heat.

[1] Ehrenheim, "Om Climaternes rörlighet" ("On the Variability of the Climates"), *K. Vet. Ak. Stockholm*, 1824, p. 178: "In our newspapers for 1817 we have read a letter from Wadsö, where they complained that the climate of later times has become harder; the wood becomes extinct; the line for forest growth is going downwards from the heights; where trees are dying new ones do not come up; in the turf mosses in the Alps one finds tree stems and roots where no trees are now growing."

[2] Gunnar Andersson, *Svenska växtverldens historia*, 2dra uppl., Stockholm, 1896, p. 82 and following ("The History of the Swedish Vegetation," 2nd ed.); "Studier öfver Finlands torfmossar och fossila kvartärflora "("Studies on the Turf Mosses and Fossil Quaternary Flora of Finland"), *Bulletin de la Commission géologique de Finlande*, No. 8, Helsingfors, 1898.

[3] See also H. Hedström, "Om hasselns forntida och nutida utbredning i Sverige" ("On the Former and Present Extension of the Hazel in Sweden"), *Geol. Fören. Förhandl.* Bd. 15, 1893. Hedström concludes that the time of this milder climate falls at and nearest after the maximal extension of the Litorina Sea.

Comparing the former and present northern limits of the hazel with the position of the mean isotherms for the year, Andersson finds a decrease of about 2° C. in the average yearly temperature of Northern and Middle Sweden from the warmest time of the Oak Age to the present time.

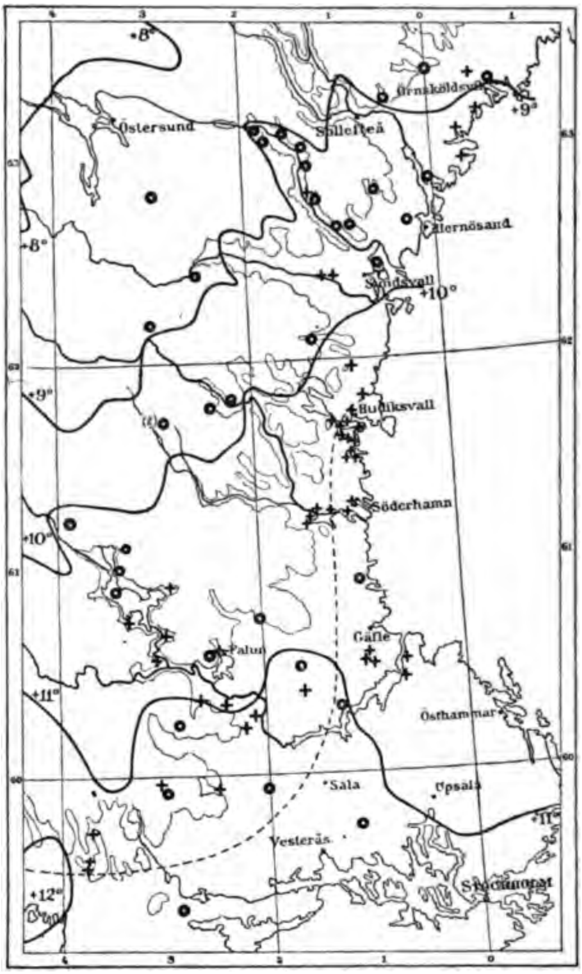

FIG. 3.—Map showing the occurrence of the hazel as Fossil (o) and Living (+) in Middle and North Sweden, according to Gunnar Andersson. The thick continuous lines designate the isotherms of the Summer half of the Year (April to September inclusive) on an average for 1860-1894. They are true isotherms, not reduced to sea-level. The dotted line indicates the present northern limit of a more frequent occurrence of the hazel (also according to Gunnar Andersson). The thin continuous line represents the curve of a height of 200 metres above sea-level.

As we shall see, there is, however, no reason to believe that the temperature of the winter half of the year has been sensibly different now from what it was then. And, in fact, the flora of so northern a country as Sweden cannot give any trustworthy evidence for judging

of any little variation in the winter temperature. If we consider the isotherms only for the summer half of the year, we find likewise a decrease of temperature amounting to about $1\frac{1}{2}°$ to 2° C. from the warmest time of the Oak Age up to our time.[1] This is illustrated by the accompanying chart, Fig. 3.

I shall now show that all this Quaternary variation of climate may be simply and completely explained by means of the long-period variations in the obliquity of the ecliptic, *i.e.* the dihedral angle between the planes of the equator and the earth's orbit. The most reliable calculation of this is considered to be that made by J. N. Stockwell.[2] I have tabulated the formula given by him[3] from 100,000 years before down to 50,000 years after our time, and therefrom drawn the curve shown in Fig. 4. According to the formula, the mean value of the obliquity

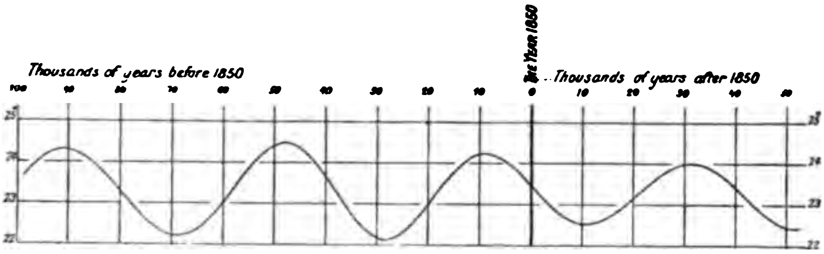

FIG. 4.

is equal to 23°·288, the greatest 24°·600, and the least 21°·977. But the greatest and least values which occur during the above-named time of 150,000 years are found to be :—

Year.	Maximum.	Year.	Minimum.
− 91,014	24°·31	− 68,759	22°·22
− 48,022	24·47	− 28,296	22·13
− 9,076	24·24	+ 10,144	22·53
+ 31,387	24·01	+ 51,618	22·42

where the years are reckoned from 1850 backward (−) and forward (+).

[1] It is not impossible that the Polar tribes lived farther to the north during the warm time 9000 years ago than nowadays. According to Kurt Hassert ("Die Nordpolar-Grenze der bewohnten und bewohnbaren Erde," *Petermann's Mittheilungen*, 37 Bd., 1891, p. 141, Chart: Tafel 11), the Esquimaux once lived much farther to the north than now in the Arctic Archipelago of North America and in Greenland, viz. north of the 75th latitude, and at Kennedy's Channel between Grant Land and Greenland even up to 82° N. Also the islands of New Siberia were once inhabited. We know nothing else, however, about the date for this. See also the next chapter, p. 51, the first note.

[2] J. N. Stockwell, "Memoir on the Secular Variations of the Elements of the Orbits of the Eight Principal Planets," etc., *Smithsonian Contributions to Knowledge*, vol. xviii., Washington, 1873.

[3] J. N. Stockwell, *l.c.* p. 174. For my purpose I have put the formula in the following simplified form :—

$$\begin{aligned} e = 23·288 &- 0·806 \cos(0·008\,897\,04t + 251·75) \\ &- 0·210 \cos(0·009\,179\,13t + 292·83) \\ &+ 0·165 \cos(0·006\,806\,58t + 306·32) \\ &- 0·069 \cos(0·012\,586\,71t + 21·11) \\ &+ 0·054 \cos(0·012\,179\,48t + 132·68) \\ &- 0·006 \cos(0·013\,200\,60t + 133·94) \\ &- 0·001 \cos(0·013\,826\,83t + 20·52) \end{aligned}$$

where e signifies the obliquity at t Julian years after 1850, and all the numerical coefficients are expressed in degrees and decimals of a degree.

But the greater this angle is, the warmer, and the less it is, the cooler, will be the summer of the northern countries, and that for two reasons. When, for instance, the angle has its maximum, the polar circle arrives at its southernmost position, and by consequence both the time during which the sun is above the horizon in summer attains its greatest length, and also the sun its greatest height in the sky, and both these circumstances increase the summer heat. The inverse will be the case when the angle has its least value. Thus a periodic variation of the climate occurs, the length of the period being about 40,000 years, and alternately warmer and cooler intervals of about 20,000 years result. The warmest epochs occurred, as will be seen from the above Table, or from the curve in Fig. 4, about 91,000, 48,000 and 9000 years ago, and will occur after about 31,000 years, etc. It is obvious that the warm time 9000 years ago coincides with that calculated by Gunnar Andersson, when the warmest time of the Oak Age occurred. By a nearer inspection of the curve, it may be found that this warm time must have continued, with little variation, about from 11,000 to 7000 years before our time, and thus during about 4000 years; for the angle between the equator and the ecliptic has varied only little during these 4000 years. But since that time the angle has gradually decreased, which has caused a continual lowering of the summer temperature. This will continue still for 10,000 years, after which time this deterioration of climate will reach its culmination. From the table or the curve one may see that cold intervals occurred about 69,000 and 28,000 years ago, and will occur after 10,000 and 52,000 years.

The most interesting to us among these intervals are that with a low summer temperature which occurred 28,296 years before 1850, and that with a high summer temperature which occurred 9076 years before that year, because these must certainly have had influence on the climate of the Quaternary Age. We shall now examine how great this influence was. Firstly, as to the length of the time during which the sun is continually above the horizon about midsummer. I have calculated it for Karesuando, the most northern meteorological station of Sweden (68° 26′ N., 22° 30′ E. fr. Gr.).[1]

We find that this time lasted

from June 3 to	July 10	inclusive, *i.e.*	38 days,	28,300 years ago.
„ May 22 to	„ 22	„	62 „	9100 „
„ May 26 to	„ 18	„	54 „	at present.

It is obvious that so great a variation in the length of the time during which the sun is above the horizon cannot be without influence

[1] Let δ be the declination and α the right ascension of the sun, and ϵ the obliquity of the ecliptic, then we have

$$\tan \delta = \tan \epsilon \sin \alpha,$$

where, with a sufficient approximation, we may take for α the values published for any year in the *Nautical Almanac*. By this approximation we neglect the variations depending upon the secular variations in the eccentricity of the earth's orbit and in the longitude of its perihelion; but as the total amount of insolation is constant for a given angle of the ecliptic, an increase of intensity of insolation will always be compensated by a shortening of the duration, so that the result will be essentially the same as if the eccentricity and the longitude of perihelion were constant.

Let ϕ be the latitude of the station, and put 35′ for the horizontal refraction, then the sun will be continually above the horizon as long as

$$\delta > 90° - \phi - 35'.$$

on the temperature and the vegetation. Such a variation occurs in all latitudes, though, of course, it is not so great south of the Arctic Circle.

Further, in order to determine the influence on the temperature, I have, according to the methods indicated by Meech,[1] Wiener,[2] and Zenker,[3] calculated the relative intensity of the insolation for the 15th of every month, and for every 5th latitude in the northern hemisphere, during the three epochs in question,[4] and then, by taking the difference between the values for the two old epochs and those for the present time, calculated the overplus or the defect of insolation at these epochs compared with the present time.

In this manner I obtained the following Table III., p. 42:—

In this Table the mean insolation falling on the earth in twenty-four hours is assumed to be 720 gram-calories per square centimetre, corresponding to a solar constant equal to 2. See Chapter 3, p. 19, and the foregoing note.

Further, as shown in Chapter 3, p. 19, by means of the differences in the Table I. and the mean temperatures of the parallels known from meteorological observations, I have calculated the differences from the present temperatures which correspond to those overpluses or defects of daily insolation. In this manner the following Table IV., p. 43, was obtained:—

As the differences of temperature given in the above Table are deduced only from the differences of insolation, they are valid, of course, only on the supposition that the differences of heat are consumed in heating the air and ground, and not in melting ice or snow and evaporating water, and that the absorbed solar heat benefits the place where it strikes, and is not carried by means of winds and ocean currents to other regions. Also, as the values are means for the parallel circles, and calculated irrespectively of the different quantities of clouds or transparency of the air, there may be local anomalies to be borne in mind in the application of the Table.

[1] Meech, "On the Relative Intensity of the Heat and Light of the Sun," etc., *Smithsonian Contributions to Knowledge*. Washington, 1856.

[2] Wiener, "Ueber die verhältnissmässige Bestrahlungsstärke," etc., *Schlömilch's Zeitschr. für Mathematik und Physik*, 1877, Th. 22.

[3] W. Zenker, *Die Vertheilung der Wärme auf der Erdoberfläche*. Berlin, 1888.

[4] Also in this calculation I have taken the right ascension α and the radius vector r of the earth from the *Nautical Almanac* (1883), thus considering the eccentricity and the longitude of perihelion as constants. This, for the reason above mentioned, introduces no error of practical importance. Assuming the cosine law for oblique rays, putting δ constant during a day, designating by H the half day-arc and by A′ the insolation in gram-calories per square centimetre for perpendicular rays during a true solar day of a length of t seconds mean solar time, when the radius vector of the earth r is expressed in its mean value as unity, we get, ϕ being the latitude,

$$\text{Sum of insolation during that day} = 2A'(\sin\phi \sin\delta \cdot H + \cos\phi \cos\delta \cdot \sin H).$$

Now if A designates the insolation in the same units as A′ during 24 hours = 86,400 seconds mean solar time, when the earth is at its mean distance from the sun, we have

$$A' = \frac{t}{86{,}400 r^2} \cdot A.$$

In order to be able to apply afterwards the method of calculation explained above (Chapter 3, page 19), I put now the absorbed insolation equal to $\frac{2}{3}$ of Langley's value, thus:— $A = 2 \times 1440$, and $A' = \frac{t}{30 r^2}$. Also the values of t have been taken from the *Nautical Almanac*.

TABLE III.—OVERPLUS (+) OR DEFECT (−) OF THE INSOLATION IN GRAM-CALORIES PER CM^2 IN TWENTY-FOUR HOURS COMPARED WITH RECENT INSOLATION (1883) FOR THE 15TH OF EVERY MONTH.

28,300 *years ago.*

Lat. N.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
°	°	°	°	°	°	°	°	°	°	°	°	°
90	0·0	0·0	0·0	−29·5	−50·0	−58·7	−56·4	−39·9	−9·4	0·0	0·0	0·0
85	0·0	0·0	+2·3	−29·4	−49·7	−58·5	−56·2	−39·7	−6·6	0·0	0·0	0·0
80	0·0	0·0	+3·0	−25·8	−49·1	−57·8	−55·5	−39·3	−6·0	+ 5·1	0·0	0·0
75	0·0	+ 7·2	+3·1	−19·9	−48·2	−56·7	−54·5	−32·7	−5·2	+ 8·5	0·0	0·0
70	+ 0·1	+11·5	+3·0	−17·3	−39·6	−55·1	−53·0	−26·9	−4·9	+ 9·5	+ 8·3	0·0
65	+12·6	+13·2	+3·0	−15·8	−31·7	−43·8	−39·4	−23·4	−4·4	+ 9·9	+13·7	+10·0
60	+16·9	+14·0	+2·9	−14·4	−27·4	−35·6	−32·4	−20·0	−4·2	+10·0	+16·4	+16·2
55	+18·9	+14·5	+2·9	−12·9	−23·7	−29·7	−27·6	−18·1	−4·0	+10·2	+17·5	+19·2
50	+19·6	+14·1	+2·7	−11·8	−20·0	−25·4	−24·2	−15·9	−3·5	+10·0	+18·1	+20·9
45	+19·8	+13·8	+2·3	−10·3	−17·2	−21·3	−20·8	−14·0	−3·0	+ 9·6	+18·4	+21·1
40	+20·0	+13·1	+2·0	− 9·3	−13·9	−17·4	−17·4	−12·0	−2·3	+ 8·8	+17·9	+21·5
35	+19·4	+12·4	+1·9	− 8·0	−11·8	−13·6	−14·1	−10·0	−2·0	+ 8·5	+17·1	+21·1
30	+18·7	+11·5	+1·9	− 6·7	− 8·1	−10·1	−11·0	− 7·7	−1·8	+ 7·3	+16·1	+20·2
25	+17·4	+10·3	+1·6	− 5·7	− 5·6	− 7·1	− 7·6	− 5·8	−1·2	+ 6·4	+14·6	+18·8
20	+15·9	+ 9·1	+1·3	− 3·9	− 3·1	− 3·0	− 4·7	− 3·6	−0·8	+ 5·2	+13·0	+17·5
15	+13·7	+ 7·9	+1·1	− 2·6	− 0·5	+ 0·3	− 1·0	− 1·8	−0·1	+ 4·0	+11·2	+15·7
10	+11·5	+ 6·5	+0·8	− 1·2	+ 1·5	+ 3·0	+ 2·0	+ 0·2	0·0	+ 3·2	+ 9·2	+13·3
5	+ 9·5	+ 4·6	+0·4	− 0·4	+ 3·6	+ 5·8	+ 4·5	+ 1·8	+0·1	+ 2·3	+ 7·5	+10·6
0	+ 7·1	+ 2·8	+0·2	+ 1·7	+ 5·1	+ 7·6	+ 6·7	+ 3·1	+0·2	+ 1·3	+ 5·6	+ 8·2

9100 *years ago.*

Lat. N.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
°	°	°	°	°	°	°	°	°	°	°	°	°
90	0·0	0·0	0·0	+17·4	+32·5	+35·4	+33·5	+24·7	+5·8	0·0	0·0	0·0
85	0·0	0·0	−1·2	+17·3	+32·4	+35·2	+33·4	+24·6	+3·9	0·0	0·0	0·0
80	0·0	0·0	−1·4	+16·5	+32·0	+34·8	+33·1	+24·4	+3·4	−2·7	0·0	0·0
75	0·0	−4·7	−1·5	+11·9	+31·4	+34·0	+32·4	+21·5	+3·1	−5·0	0·0	0·0
70	0·0	−6·8	−1·6	+10·5	+27·6	+32·6	+31·5	+16·9	+3·0	−5·8	− 3·8	0·0
65	− 6·9	−8·0	−1·7	+ 9·2	+21·4	+27·6	+25·6	+14·5	+2·9	−6·3	− 8·0	− 4·5
60	− 9·5	−8·6	−1·7	+ 8·0	+19·0	+22·1	+20·4	+13·1	+2·8	−6·3	− 9·9	− 9·0
55	−10·6	−8·7	−1·6	+ 7·0	+17·0	+18·5	+16·9	+11·8	+2·6	−6·2	−10·8	−11·0
50	−11·2	−8·3	−1·5	+ 6·5	+15·1	+15·0	+14·2	+10·5	+2·4	−6·0	−11·0	−12·2
45	−11·9	−8·0	−1·4	+ 5·7	+13·3	+12·2	+11·9	+ 9·1	+2·1	−5·7	−11·0	−13·0
40	−12·0	−7·6	−1·3	+ 4·8	+11·5	+ 9·8	+ 9·6	+ 8·0	+1·6	−5·3	−10·9	−13·0
35	−11·8	−7·1	−1·1	+ 4·0	+ 9·4	+ 7·7	+ 8·0	+ 6·8	+1·4	−5·0	−10·3	−12·8
30	−11·2	−6·6	−1·0	+ 3·3	+ 8·0	+ 6·0	+ 6·2	+ 5·5	+1·2	−4·6	− 9·7	−12·2
25	−10·5	−6·0	−0·8	+ 2·5	+ 6·2	+ 4·0	+ 4·4	+ 4·0	+1·0	−4·0	− 8·9	−11·7
20	− 9·6	−5·2	−0·5	+ 1·9	+ 4·3	+ 2·1	+ 2·4	+ 3·1	+0·7	−3·4	− 8·0	−10·4
15	− 8·6	−4·3	−0·3	+ 1·0	+ 2·9	+ 0·1	+ 0·7	+ 1·9	+0·4	−2·7	− 7·2	− 9·4
10	− 7·7	−3·2	−0·2	+ 0·5	+ 0·6	− 1·5	− 1·2	+ 0·4	+0·3	−2·0	− 6·1	− 8·1
5	− 6·1	−2·3	−0·1	− 0·5	− 1·6	− 3·5	− 3·0	− 1·0	0·0	−1·1	− 4·5	− 7·0
0	− 4·5	−1·5	−0·1	− 1·0	− 3·7	− 5·0	− 4·3	− 2·2	−0·2	−0·6	− 3·5	− 5·4

TABLE IV.—Showing how much the Mean Temperature of each Month was Higher (+) or Lower (−) than at Present for Different Latitudes.

28,300 *years ago.*

Lat. N.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Apr.-Sept.	Oct.-Mar.
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
90	0·0	0·0	0·0	−3·7	−6·3	−7·3	−7·1	−5·0	−1·2	0·0	0·0	0·0	−5·1	0·0
85	0·0	0·0	+0·3	−3·7	−6·2	−7·3	−7·0	−5·0	−0·8	0·0	0·0	0·0	−5·0	+0·1
80	0·0	0·0	+0·4	−3·3	−6·1	−7·2	−6·9	−4·9	−0·7	+0·7	0·0	0·0	−4·9	+0·2
75	0·0	+1·0	+0·4	−2·5	−6·0	−6·3	−6·1	−4·1	−0·6	+1·2	0·0	0·0	−4·3	+0·4
70	0·0	+1·6	+0·4	−2·2	−4·4	−6·1	−5·9	−3·4	−0·6	+1·2	+1·0	0·0	−3·8	+0·7
65	+1·6	+1·7	+0·4	−2·0	−3·5	−4·4	−3·9	−2·6	−0·5	+1·2	+1·7	+1·3	−2·8	+1·3
60	+2·1	+1·8	+0·4	−1·6	−3·0	−3·6	−3·2	−2·0	−0·5	+1·2	+2·0	+2·0	−2·3	+1·6
55	+2·3	+1·8	+0·4	−1·3	−2·4	−3·0	−2·8	−1·8	−0·4	+1·1	+2·1	+2·4	−2·0	+1·7
50	+2·4	+1·6	+0·3	−1·2	−2·0	−2·3	−2·2	−1·4	−0·4	+1·1	+2·0	+2·6	−1·6	+1·7
45	+2·3	+1·5	+0·3	−1·0	−1·7	−1·9	−1·9	−1·3	−0·3	+1·0	+1·9	+2·5	−1·4	+1·6
40	+2·2	+1·4	+0·2	−0·9	−1·3	−1·6	−1·6	−1·1	−0·2	+0·9	+1·8	+2·4	−1·1	+1·5
35	+2·2	+1·2	+0·2	−0·7	−1·1	−1·2	−1·3	−0·9	−0·2	+0·9	+1·7	+2·1	−1·1	+1·4
30	+2·1	+1·1	+0·2	−0·6	−0·7	−0·9	−1·0	−0·7	−0·2	+0·7	+1·6	+2·0	−0·6	+1·3
25	+1·8	+1·0	+0·2	−0·4	−0·5	−0·6	−0·7	−0·5	−0·1	+0·6	+1·4	+1·9	−0·5	+1·2
20	+1·6	+0·8	+0·1	−0·3	−0·3	−0·3	−0·4	−0·3	−0·1	+0·5	+1·2	+1·6	−0·3	+1·0
15	+1·3	+0·7	+0·1	−0·2	0·0	0·0	−0·1	−0·2	0·0	+0·4	+1·0	+1·4	0·0	+0·8
10	+1·0	+0·6	+0·1	−0·1	+0·1	+0·3	+0·2	0·0	0·0	+0·3	+0·8	+1·2	+0·1	+0·7
5	+0·9	+0·4	0·0	0·0	+0·3	+0·5	+0·4	+0·2	0·0	+0·2	+0·7	+1·0	+0·2	+0·5
0	+0·6	+0·3	0·0	+0·1	+0·5	+0·7	+0·6	+0·3	0·0	+0·1	+0·5	+0·7	+0·4	+0·4

9100 *years ago.*

Lat. N.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Apr.-Sept.	Oct.-Mar.
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
90	0·0	0·0	0.0	+2·5	+4·1	+4·4	+4·2	+3·1	+0·7	0·0	0·0	0·0	+3·2	0·0
85	0·0	0·0	−0·2	+2·2	+4·1	+4·4	+4·2	+3·1	+0·5	0·0	0·0	0·0	+3·1	0·0
80	0·0	0·0	−0·2	+2·1	+4·0	+4·4	+4·1	+3·1	+0·4	−0·3	0·0	0·0	+3·0	−0·1
75	0·0	−0·6	−0·2	+1·5	+3·9	+4·3	+4·1	+2·7	+0·4	−0·6	0·0	0·0	+2·8	−0·2
70	0·0	−0·9	−0·2	+1·3	+3·5	+3·6	+3·5	+1·9	+0·4	−0·7	−0·5	0·0	+2·4	−0·4
65	−0·9	−1·0	−0·2	+1·2	+2·7	+2·8	+2·6	+1·5	+0·3	−0·7	−1·0	−0·6	+1·9	−0·7
60	−1·2	−1·1	−0·2	+0·9	+1·9	+2·2	+2·0	+1·3	+0·3	−0·7	−1·1	−1·1	+1·4	−0·9
55	−1·3	−1·1	−0·2	+0·8	+1·7	+1·9	+1·7	+1·2	+0·3	−0·7	−1·2	−1·3	+1·3	−1·0
50	−1·4	−1·0	−0·2	+0·7	+1·5	+1·5	+1·4	+1·1	+0·2	−0·6	−1·2	−1·4	+1·1	−1·0
45	−1·5	−0·9	−0·1	+0·6	+1·3	+1·2	+1·1	+0·8	+0·2	−0·6	−1·2	−1·4	+0·9	−1·0
40	−1·4	−0·8	−0·1	+0·5	+1·2	+0·9	+0·9	+0·7	+0·2	−0·5	−1·1	−1·3	+0·7	−0·9
35	−1·2	−0·7	−0·1	+0·4	+0·9	+0·7	+0·7	+0·6	+0·1	−0·5	−1·0	−1·2	+0·6	−0·8
30	−1·1	−0·6	−0·1	+0·3	+0·8	+0·5	+0·6	+0·5	+0·1	−0·4	−1·0	−1·2	+0·5	−0·7
25	−1·0	−0·5	−0·1	+0·2	+0·6	+0·4	+0·4	+0·4	+0·1	−0·4	−0·9	−1·1	+0·4	−0·7
20	−0·9	−0·5	−0·1	+0·2	+0·4	+0·2	+0·2	+0·3	+0·1	−0·3	−0·8	−1·0	+0·2	−0·6
15	−0·8	−0·4	0·0	+0·1	+0·3	0·0	+0·1	+0·2	0·0	−0·2	−0·7	−0·9	+0·1	−0·5
10	−0·7	−0·3	0·0	0·0	+0·1	−0·1	−0·1	0·0	0·0	−0·2	−0·6	−0·7	0·0	−0·4
5	−0·6	−0·2	0·0	0·0	−0·1	−0·3	−0·3	−0·1	0·0	−0·1	−0·4	−0·6	−0·1	−0·3
0	−0·4	−0·1	0·0	−0·1	−0·3	−0·5	−0·4	−0·2	0·0	−0·1	−0·3	−0·5	−0·2	−0·2

Now, considering first the condition 28,300 years ago, we see that the summer half of the year was then cooler than now, viz. not less than 5° C. between the Pole and 80° N., and from $3\frac{1}{2}$° to 2° C. in Sweden. As to the polar region, this might signify partly that the temperature was really somewhat lower, partly that a less quantity of snow and ice was melted by the summer sun at that time than at present. But as to Sweden, certainly almost the whole diminution of heat has shown itself as fall of temperature. It will be worthy of an inquiry, if there did not perhaps occur at that time a local increase of glaciation within the Kola Peninsula, Jemtland, and other countries, as has been pointed out by several geologists.[1] No doubt the fall of temperature is considerable enough to produce such an effect.

But as to the winter half of the year, it is rather uncertain if the temperature then was 1° or 2° C. higher than now, as the calculation indicates. For, as shown by the temperature charts[2] for Sweden, the January temperature of our country is about 12° C. higher than it ought to be according to the latitude, and the overplus for the whole winter half of the year will probably not be much less. But this great positive anomaly is due exclusively to the influence of the Atlantic continuation of the Gulf Stream and the warm South-westerly winds produced by it and by other causes. It might have been that the overplus of temperature on the Atlantic from 20° to 60° N. lat. 28,300 years ago so much enfeebled the Gulf Stream that the winter was not milder than now.

Further, considering the state of the temperature 9100 years ago, we see that the summer half of the year was warmer then than now, viz. between the Pole and 75° N. about 3° C., and in Sweden from 2° to 1°·3 C., which perfectly agrees with the result deduced from the above inquiry of Gunnar Andersson's on the northern limit of the hazel in Sweden at both epochs, and with the other conclusions drawn by geologists and botanists from their inquiries. As the overplus of temperature amounted to fully 2° C. in Middle Sweden and Southern Finland, and moreover the sun remained above horizon longer than now, it will be quite explicable that the water-calthrop could then ripen its fruits in the lakes of these regions.

As to the winter, we cannot here draw any conclusions. But it might be possible that this season, owing to the influence of the Atlantic continuation of the Gulf Stream, was as mild, or even milder, then as it is at present.

Still, a conclusion of great climatic and geological interest may be drawn from our curve (Fig. 4) or Table of the variation of the obliquity of the ecliptic. Indeed we have already remarked that a period with warm summers ought to have occurred 48,000 years ago. Now, as however the phyto-paleontologists of our country have not discovered more than one marked period of a richer and more southerly type than now, viz. that which occurred 9000 years ago, we must assume that 48,000 years ago the ice covering Sweden during the Great Ice Age had not yet melted away completely, or at least had so lately melted that a richer flora had had no sufficient time to establish itself. *Thus the end*

[1] Gunnar Andersson, "Den Centraljämtska issjön" ("The Ice Lake of Central Jemtland"), *Ymer*, 1897, p. 63.
[2] N. Ekholm, *Ymer*, 1899, *l.c.*

of the Great Ice Age cannot have occurred more than about 50,000 *years ago.* It may possibly have occurred later, but it seems not improbable that the exceptionally intense insolation which, according to the formula of Stockwell, must have taken place during the summer of the northern countries from 50,000 to 46,000 years ago has materially contributed to the melting away of the ice covering, and thus put an end to the Great Ice Age. The principal cause of the gradual rise of temperature about that time must, of course, be attributed to a slow increase of the quantity of carbonic acid in the air, as shown in the two foregoing chapters.

The periodic climatic variation here discussed cannot, as far as I can judge, have caused any sensible variation of the rain. The rather damp and rainy period with mild winters which, according to the opinion of most geologists, has occasioned the immigration of the Ilex flora to the west coast of Scandinavia cannot therefore be explained thereby. Possibly such a variation of climate was caused exclusively by geographical causes, as, during the land depression called by Swedish geologists the Litorina depression, the lukewarm water of the North Sea had a more open access to the coasts of the Scandinavian Peninsula than it has now.

According to the opinion of some Scandinavian botanists, particularly Axel Blytt and Rutger Sernander, the Scandinavian Peninsula has had several alternating periods of dry and damp climates during the Quaternary Age, which have given rise to alternating growths of wood and moss, indicated by alternating layers of tree-stools and moss in the Scandinavian swamps. As it seems to me at present impossible either to contest or to confirm this opinion by means of physical investigation, it may be left to future research, so much the more as the question is still much in dispute among botanists and geologists.

After writing the above, I have found that this point has already been considered by J. Croll,[1] who, by a method of calculation different from that which I used, obtained a result as to the temperature of the poles during the summer that does not differ noticeably from that given in this paper. According to Croll:[2] "When the obliquity of the ecliptic was at a maximum, and the poles were receiving $\frac{1}{18}$th more heat than at present, the temperature of the poles ought to have been about 14° or 15° Fahr. warmer than at the present day, provided, of course, that this extra heat was wholly employed in raising the temperature. Were the polar regions free from snow and ice, the greater portion of the extra heat would go to raise the temperature. But as these regions are covered with snow and ice, the extra heat would have no effect in raising the temperature, but would simply melt the snow and ice. The ice-covered surface upon which the rays fell could never rise above 32°. At the period under consideration the total annual quantity of ice melted at the poles would be $\frac{1}{18}$th more than at present." So far Croll. If we suppose, in agreement with the statement made by Croll on p. 400, that the rise of 14° or 15° Fahr. is meant to take place under the above condition only during the middle of summer, then Croll's result agrees very closely with that given here. But supposing that

[1] J. Croll, *Climate and Time*, London, 1875, p. 398 *et seq.*
[2] J. Croll, *l.c.* p. 402.

the yearly average were considered, a rise of 14° or 15° Fahr. would be about three times too much. Also the remarks of Croll as to the influence of this variation on the temperature in other latitudes are essentially correct. But as the biological and geological facts, which in this paper are explained as a consequence of the variations of the obliquity of the ecliptic, were still very little known in 1875, Croll did not develop his theory on this matter more in detail. And as the variation of the eccentricity of the earth's orbit is, according to him, the principal cause of the great changes of climate during the geological past, his chapter on the obliquity of the ecliptic seems not to have been duly estimated. I wish now to acknowledge Croll's indisputable priority as to the theory in question.

7. *Climatic variations during historical times, particularly in North-Western Europe.*

It remains to consider the variations of the climate during the historical period. Here we certainly find a richer material of observations than before, but at the same time such a want of order and regularity that it seems at present nearly impossible to obtain a survey of and establish a connection between the shifting phenomena. Here we cannot see the wood for trees. First, during the last hundred or hundred and fifty years, since there began to be regular meteorological observations, the survey becomes easier; but then, on the other hand, the time is too short, so that from this reason no reliable conclusions can be drawn. Moreover, the material is so rich that the energy of a single man is insufficient to work it out. I must then confine myself to a short sketch of the climate of Scandinavia and the adjacent countries.

Almost the only weather phenomenon of which the old chronicles give trustworthy reports are severe winters. The following statements thereof are partly taken from Ehrenheim,[1] partly collected by Prof. R. Rubenson and by him kindly placed at my disposal. The year of the winter is determined by January, yet it is sometimes doubtful whether the chronicler has not taken it from December. Sometimes the winter is indicated by the numbers of both years separated by a break. Possibly in some case a severe winter has thereby been doubled.

The Skager Rack and the Catte Gat (Ehrenheim writes, "the North Sea between Norway and Denmark") were frozen and available for traffic for men and animals in the winters 1048, 1224-25, 1294 and 1296(?) [people rode from Oslo (Christiania) to Jutland], 1394, 1399, 1407-8, 1423-24.

The south part of the Baltic was covered with ice which would bear traffic in the winters 1294, 1306 (people travelled over the ice between Öland, Gotland, and Esthonia), 1322-23 (people walked and rode between Denmark and Germany, and between Scania and Sealand, and had regular lodgings on the ice), 1324 (the Baltic was frozen during six weeks), 1393-94 and 1399 (people walked between Denmark and Pomerania), 1407-8 and 1418 (people walked on the ice between Germany and Denmark), 1423-24 (people rode on the ice from Danzig to Lubeck, and had lodgings on the ice), 1426 (similar winter), 1458-59

[1] Ehrenheim, "The Variability of the Climates," cited above.

and 1459-60 (the whole Baltic was covered with ice, so that people went on foot and on horseback from Germany to Sweden and Denmark, likewise from Livonia, and this still at the end of March), 1545 and 1546 (?) (the Baltic frozen between Mecklenburg and Denmark), 1573 (on the Thursday before Whitsuntide people came on the ice from Sweden to Reval), 1636 (people walked on the ice from Scania to Bornholm till March 21), 1658 (the Swedish army went over the Little Belt), 1670 (the Little and Great Belts frozen), 1708-9 (the Belts and the Sound covered with ice, people travelled on the ice from Gothenburg to Marstrand, and still in June ice was left between the cliffs along the shore of the Baltic east from Stockholm. The Baltic was covered with ice as far as could be seen by means of telescope from the church steeple of Danzig. The port of Genoa was partly frozen, the Adriatic covered with ice, which had not happened since 859), 1776 (the Sound and the Belts frozen, likewise the Zuider See, but not the Sea of Åland, N.W. from Stockholm).

Also from middle and south of Europe both Ehrenheim and foreign meteorologists report accounts taken from the old chronicles about winters so severe that they far surpass those of our time. According to Ehrenheim, these winters began to occur about 300 years before Christ, and then have been comparatively frequent during the first thousand years of our era. In the year 250 the Thames was frozen for nine weeks; 508 English ships were imprisoned by the ice for two months. The Black Sea was frozen several times, 401 (in twenty days), 673 (ice several ells thick), 800-801 (ice several feet thick). In 763 all the Black Sea, and even the Dardanelles, were filled with ice; in the same winter the snow in many places lay 50 feet deep. The Adriatic was covered, 859-60, with ice which bore traffic. In 717 all Asia Minor was covered with snow during three months. In 1216 the Po was covered with ice, likewise in 1234 when the ice around Venice supported heavy waggon loads. From November 1334 to March 1335 a severe cold reigned in all Europe; all rivers in Italy were frozen. In 1608 the Bosphorus was covered with ice, in 1621 likewise, and moreover the Gulf of Venice.

"One might conclude," says Ehrenheim, "that the extremes of cold have decreased from the following facts:—since 1424 there is no instance that the Skager Rack has been frozen, since 1573 none that people have gone on the ice from Livonia to Sweden and Denmark, since 1621 none that the Bosphorus has been covered with ice, since 1635 (1636 ?) none that the Baltic has borne traffic between Scania and Bornholm, since 1709 none that ice has been prevalent in the Adriatic."

On the other side, according to Ehrenheim, the summers of Western Europe have become cooler. "In Normandy the vine in older times was cultivated with great success, and it was in the Middle Ages that the vineyards north from the Cevennes were celebrated. In the fourteenth century people were at last obliged to abandon this culture, and instead of it to plant apple trees in order to make cider. The Paris wines were formerly served at kings' tables. In Languedoc there were, until 1561, great vineyards on the slope of the mountain range that divides the province; there now grapes cannot even redden. In England also the vine had been cultivated during all the Middle Ages ever since the time

of the Romans, and there exist old household accounts of hogsheads of wine produced in the vineyards of Northampton and Leicester." Thus "we find here again the contrast that the vine produced ripe grapes in England and Normandy at a time when the Skager Rack froze, but has not been able to do the same afterwards when this winter cold had ceased."

The first conclusion of Ehrenheim, viz. that the extremes of winter cold have decreased, seems indisputable if we compare the state of the ice in the Scandinavian waters formerly and now. Nowadays (during the nineteenth century, more detailed reports since 1870) this is as follows. On the west and south coast of Sweden the navigation is only during severe winters somewhat hindered by ice, mostly by drifting ice. Compact sea ice within sight from the outermost lighthouses, as Vinga and Väderöbod, is rare, continues ordinarily only for a few days, and in extremely rare cases will bear a man, as for instance in February and March 1888. About the same are the ice conditions on the Skager Rack along the south-east coast of Norway. At the end of February 1893, however, the sea was covered with ice along the whole coast from Christiansand (Oxö) to Christiania, as far as the eye could see. During very severe winters the Sound has been covered with ice which would bear waggons. The northern and middle portions of the Baltic, from the Sea of Åland to the south end of Gotland, Öland and Calmar Län (government), outside the cliffs along the shore, are covered with ice only during very severe winters, and then ordinarily only for a few days or even weeks, and only for ten or twenty kilometres from the coast. Drifting ice is more common, and during very severe winters may be piled up in gigantic masses of crowded ice. Thus on February 25, 1893, they reported from Sandhamn (59° 17′ N., 18° 56′ E. fr. Gr., a port east of Stockholm): "The solid ice is lying 1½ mile outwards; . . . farther outside the sea is filled up by very heavy drifting ice, high as the rigging of the largest ship." It is only during very mild winters that the navigation can go on quite without hindrance; between Stockholm and Visby it ceases, on an average, in the end of December and begins again about April 10. During very severe winters the Sea of Åland is covered with ice which bears traffic. The Botten Sea (= south part of the Gulf of Bothnia) is covered with ice every winter along the coasts, but rarely, if ever, in its central part. The navigation there is interrupted, by compact or drifting ice, on an average from the middle of November to the beginning of May, with some difference for different ports and up to a variation of six to eight weeks for different years. Sometimes it has happened that the port of Hernösand has been free from ice during a whole winter. The northern Quarken (the strait between the southern and northern parts of the Gulf of Bothnia) has been covered with ice which bore traffic about every third or fourth year since 1816, namely in the years (date = that of January) 1816, 1830, 1831, 1839, 1844, 1845, 1853, 1855, 1856, 1857, 1861, 1862, 1865, 1866, 1867, 1875, 1876, 1877, 1879, 1881, 1886, 1888, 1893, 1895, and 1897 (is said to have been strong enough this year, though the traffic was not undertaken). The Botten Gulf (= north part of the Gulf of Bothnia) is as a rule frozen every winter. The ice formation occurs along the coast on an average about the middle of November,

sometimes at the end of October or the beginning of December. The breaking up arrives on an average during the later half of May, extremely rarely in the beginning of that month, sometimes not until the beginning of June.

Thus, although a considerable formation of ice on the Scandinavian seas occurs also at the present time during severe winters, nevertheless it is evident that the ice-covering on the Baltic, the Sound, the Belts, the Catte Gat, and the Skager Rack was very much more extensive during the Middle Ages, particularly from the eleventh to the fifteenth centuries, than afterwards.[1] It is difficult for us to understand what the weather might be during a winter which covers with thick ice all the southern part of the Baltic, the Catte Gat, and the Skager Rack. Such a winter must have had not only a severe and continual cold, but also relatively calm weather, otherwise the ice would have been broken up into drifting or crowded ice-flakes, and hence not have been suited for traffic. In the above-cited paper[2] I have made a study of the severe winters in Sweden from about 1870. Such a winter begins in our time with snow-storms generated by cyclones situated south or south-east from our peninsula, *i.e.* in the southern or south-eastern part of the Baltic. Then gradually an anticyclone extends over the Norwegian Sea. Now if we imagine that these cyclones, after the whole country had been covered with snow, were pushed off always farther to the south-east as far as to the Black Sea and Asia Minor, whereas the anticyclone extended from the icy ocean and the Norwegian Sea over all Scandinavia and Finland, Western and Central Europe, and Northern Russia, and that such a state of barometric pressure was accompanied by a sky generally clear and light winds, so that a strong radiation continued during two or three months, then we might have an idea about the probable state of weather during the winters 1322-23, 1423-24, or 1459-60.

But such winter weather, as far as we know, has not occurred in our time; for the cold winters in our days are always characterised by frequent cyclones, which from time to time are passing over Sweden or not far to the south of it. Ordinarily they come from the west, and no doubt are generated or maintained by the Atlantic continuation of the Gulf Stream. It would therefore seem to be the explanation nearest at hand that the Gulf Stream was feebler or had another and more westerly direction during the Middle Ages than now, and by consequence the climate of that time was more continental than it is now. In the latter case the climate of Iceland and Greenland would have been milder than at present. I do not know, however, any plausible cause for such a variation in the direction of the Gulf Stream.

But that Iceland and Greenland at the time of their colonising by the old Scandinavians (Northmen) and afterwards during the succeeding centuries really had a somewhat milder climate than the present one seems to come out from the old sagas and chronicles of the Middle Ages, as, for instance, Ehrenheim and A. E. Nordenskiöld have pointed out. "It is now disputed," says Ehrenheim in 1824, "that the east coast of Greenland was ever inhabited and cultivated; it is indifferent when we

[1] What the conditions in our waters were before the eleventh century is unknown, as the old sagas do not tell us about it.

[2] *Ymer*, 1899, p. 221 *et seq.*

compare the whole land formerly and now. It was discovered more than 900 years ago, and history testifies that there existed woods and pasture lands inviting colonists, and that it was so successfully cultivated in agriculture and breeding of cattle that after 200 years there were to be found 196 hamlets,[1] 12 churches, several monasteries,[2] and a bishop's see. In this condition the land disappears from history in the middle of the fourteenth century, when the communications with Iceland were interrupted. During the seventeenth century Lindenau, Hudson, and many others made fruitless efforts to find this land again, and when at length it was again discovered and examined on its west coast all culture was found to have been effaced by the severity of the climate, and the wild inhabitants told Crantz that straits and inlets formerly had been navigable which now were covered with ice. This variation in the climate seems to have continued during all the eighteenth century, to judge from the decrease of the population; for where the Bishop Egede in 1723 found about 30,000 inhabitants on all the west coast, there Giesecke in 1813 found only 6583. The younger Egede, in his journal of 1770-78, tells us positively that the icebergs in Greenland are increasing yearly. Iceland, which was still more flourishing in its prosperity, has undergone a similar fate. There the woods have become extinct, the agriculture has disappeared, the population diminished by more than a half. It seemed to Von Troil that this island approached the fate of Greenland."

Ehrenheim's description of the change of the climate in Greenland might be exaggerated, but that some change in the indicated direction has occurred results from the inquiries made by the Danes during the last twenty years. G. F. Holm,[3] then first lieutenant of the Danish navy, in the years 1880 and 1881 examined the southernmost part of Greenland (the district of Julianehaab), from 61° 15′ N. and 46° 20′ W. to 60° 15′ N. and 43° 0′ W. fr. Gr., and found there a great many old ruins from the Northmen's colonies, situated mostly at the heads of the fjords between 46° 14′ and 43° 58′ W. This region has formerly been partly examined and described, especially in the great Danish work *Grönlands historiske Mindesmærker* ("The Historical Monuments of Greenland"). This is no doubt the old "Österbygden" (the chief colony), for the number of ruins found agrees very nearly with the old relations of the chroniclers.[4] Holm says (*l.c.* p. 72): "In summer there was in the neighbourhood of all the greater groups of ruins a rich store of fodder for great flocks of cows and sheep, but in what manner they in those times could find sufficient winter fodder for the cattle is difficult to understand, unless we assume that the climate formerly was milder, so that it was possible for the cattle to stay out of doors a longer time of the year than now is the case. That the ice-drift along the coast has increased in historical times is stated by the old chroniclers, and seems to be a necessary condition in order to understand how the old Northmen were able to navigate in the present district of Juliane-

[1] 190 hamlets, according to the newer statements. See farther on.

[2] Two monasteries, according to newer statements.

[3] G. F. Holm, "Description of Ruins in the District of Julianehaab" (Danish), *Meddelelser om Grönland*, 6 Heft, Kjöbenhavn, 1883, pp. 57 and 147.

[4] See further Daniel Bruun, "Archæological Inquiries in the District of Julianehaab" (Danish), *Meddelelser om Grönland*, 16 Heft, 1896, p. 171 and following.

haab; and, moreover, it cannot be denied that this ice, which now is lying everywhere outside this part of the land, considerably increases the severity of the weather." Further, he speaks (p. 74) about enclosures "situated outside the house on a fertile soil on southern slopes in the vicinity of running water," and which "perhaps have surrounded gardens"; hand-mills (p. 75) of which is said: "If the corn, as told in the old chronicles, has been cultivated there, the climate, as said above, must then have been milder than now; more probably, however, the corn has been brought to them by means of the ships." The principal business of the people was breeding of cattle (horses, cows, sheep, and goats), fishing and hunting; but, says Holm (p. 75), "that the principal trade of the Northmen has not been confined to the sea, follows from the circumstance that so many greater groups of ruins are situated in a considerable distance from the fjords." After the middle of the thirteenth century the colony began to come to ruin (*l.c.* p. 61). "The sea ice at the eastern coast of the land increased in a degree hitherto unknown; as a consequence of it shipwrecks seem to have become frequent." In the next century the navigation was moreover impeded by an injurious trade monopoly introduced by the Norwegian kings, and the Skrælings (Esquimaux) attacked the colonists. First they destroyed the north-western (now Godthaab) district (the old Vesterbygden); at last, probably at the end of the fifteenth century, also the south-eastern (now Julianehaab) district (the old Österbygden).[1] Afterwards, when the land was discovered again, the Norwegian population had disappeared. Modern Greenland (Esquimau) tales speak of struggles in which the last "Kablunaks" (Norwegians) were extirpated.[2] Holm, however, believes that the last inhabitants of the forgotten colony have gradually turned to the manner of living of the Esquimaux and mixed with them, by which the East Greenlanders have assumed a half-Norwegian type. Thus it has not been exclusively the deterioration of the climate in Greenland which has spoiled the old colony, though this may have been a contributing cause. According to Finnur Jónsson, the corn culture was very slight, or did not succeed, at least in the beginning, for not even the first chief of the land, Erik Röde (Erik the Red), had barley for his Yule ale. Daniel Bruun[3] tells us that the present Greenlanders (Esquimaux) in these regions successfully practise breeding of cattle. The cows go, as a rule, out of doors from April or May to October, and during the winter are foddered with hay which the inhabitants make along the coasts and bring home in their umiaks (women's boats). At Igaliko they have begun in the last years to plant turnips as fodder for the cattle.

As to the second statement of Ehrenheim, viz. that the summers in Western Europe during the Middle Ages were warmer than now, it is more doubtful than the former. That the vine is no longer cultivated as far to the north as formerly, several writers are inclined to explain by the assumption that people were formerly content with a worse and more acid wine than now, made even from rather unripe grapes.[4]

[1] Thus it seems as if the Esquimaux have wandered to the south, which may be considered as still a proof that the climate in Greenland has deteriorated.

[2] Finnur Jónsson, "A Brief Sketch of the History of the Greenland Colony" (Danish), *Nordisk Tidskrift*, Stockholm, 1893, p. 533.

[3] Daniel Bruun, *l.c.* p. 252 and following, p. 322 and following.

[4] Alfred Angot ("Études sur les vendanges en France," *Annales du Bureau Central*

I shall now give some observations which likewise seem to prove that the winters have become milder in the Scandinavian countries during the last three hundred years, and that at least during the last century the summers in Great Britain, Denmark, and South Sweden have been somewhat cooler—in short, that the climate has grown more maritime.

The most important of these observations are those which Tycho Brahe carried out during the period October 1582 to April 1584, and August 1584 to April 1597 inclusive (= 14 years 4 months), at his observatory, Uranienborg (55° 54′ N., 12° 43′ E. fr. Gr.), in the little island Hven in the Sound, and which have been calculated by Poul la Cour and published *in extenso* by the Royal Danish Society of Sciences.[1]

Poul la Cour finds several differences between the climate of Hven 300 years ago and the present climate in adjacent districts of Denmark—differences the signification of which, however, he seems to underrate. He remarks that the number of snow days in February is much greater according to Tycho Brahe than according to present observations, and that at the same time the number of rain days in this month is very small according to the old series, which agrees with what results from several circumstances, namely, that the month of February has been cold and severe throughout. Further, Poul la Cour finds a considerable difference in the wind directions then and now—so great, indeed, that it seems impossible to attribute it to errors of observations or to accidents. Whereas in our time South-west is the prevailing wind direction on the yearly average, and South-west or West during all months except April or May, when South-east is somewhat more frequent, in Tycho Brahe's time South-east was decidedly prevalent in the yearly average, and East or South-east during seven of the months of the year, viz. January to May inclusive, October and December, and even during the other five months the South-east wind shows a secondary maximum, of which now scarcely a trace is seen. From this we must conclude that the distribution of atmospheric pressure during the winter was then essentially different from the present one; the low pressure which in our time is to be found regularly between Norway and Greenland and in the northern ice ocean was then necessarily but little marked. Owing to this low

météorologique de France, 1883, i., Paris, 1885) has examined whether the mean date of the vine harvest in France has undergone any secular change, but has not found any progressive one, and hence concludes that the state of the vine culture does not indicate any deterioration of the summer climate there. He remarks, however, that the date of the vine harvest depends also on other circumstances than the climate. But that the mean date of the vine harvest really has been a little retarded during the last 500 years seems to follow from the averages of Dijon, which are in the fourteenth century October 25 (mean of only 13 years); in the fifteenth century, October 25 (mean of 60 years); in the sixteenth century, October 28; in the seventeenth century, October 25; in the eighteenth century, October 29; and in the nineteenth century October 30 (mean of 80 years), and from hence we might possibly conclude some secular decrease of the summer heat at Dijon. Whether the vine formerly was cultivated in regions where it does not thrive now, Angot does not tell us.

[1] Tyge Brahe's *Meteorologiske Dagbog, holdt paa Uraniborg for Aarene, 1582-1597. Udgiven som Appendix til Collectanea Meteorologica af det Kgl. Danske Videnskabernes Selskab ved dets meteorologiske Comité*, Kjöbenhavn, 1876. With a supplement: "Summary of the Weather Observations in the Meteorological Journal of Tycho Brahe," by Poul la Cour (Danish and French). During the three months May, June, and July 1584, the observer made a voyage to Fruenburg in Prussia, during which observations were also carried on. This remarkable journal contains probably one of the oldest series of meteorological observations existing.

pressure the cyclones at present are passing usually from west to east over the northern or middle part of the Scandinavian Peninsula, producing South-west winds in the Sound. But the East or South-east winds which in Tycho Brahe's time reigned during the winter prove that the cyclones then took a more southerly track, and as a rule were passing west and then south of Hven, for instance from the North Sea through the southern part of Denmark to Germany, a track at present taken by the cyclones almost exclusively during the spring months of ordinary years and during unusually severe winters. Also the North-east winds were then generally more frequent than they are now. Likewise the examination of the frequency of storms shows a difference, the number of storms in February and March being in Tycho Brahe's time less than the yearly average, whereas the case now is inverse. Moreover, the number of East and South-east storms was then relatively greater than now, as one might expect according to the different wind roses. All these differences between the climate of that time and the present one agree with what was said above of the probable distribution of pressure and weather during the severe winters of the Middle Ages.

We possess now a very complete series of observations on the temperature, rainfall, and weather at Uranienborg for the years 1881-98 inclusive, carried out by the farmer J. J. Alm, under the instruction of the Meteorological Central Office in Stockholm and by means of its instruments. Thus we are able to make a direct comparison between the climate of Uranienborg at Tycho Brahe's time and at present, although, of course, the want of meteorological instruments causes difficulties in the case of the old series.

Firstly, I have calculated the mean date of the last spring frost and the first autumn frost. The word *frost* is not to be found all years in the old series. In these cases I have used such expressions as "ice on the water in the morning," "great snow," "hail and snow," "cold snow," etc. By adding ten days to the date of Tycho Brahe it was reduced to the new style. In the new series I have counted as frost days those when the minimum temperature was below 0° C. In this manner I derived the following result:—

Year.	Last spring frost.	First autumn frost.
1582-1597 . . .	April 18	October 27
1881-1898 . . .	,, 19	,, 28

Hence it seems to follow that the conditions of temperature during the spring and the autumn have not varied.

From the observations of Tycho Brahe, Poul la Cour has calculated the probability of a day of precipitation, rain, snow, hail, thunder for every month of the new style. I have calculated corresponding values from the new observations and put the results together in the following Table. The signification of the numbers of the Table is thus: for instance, the probability of a day of precipitation in June 1582 to 1597 being 0·360, this indicates that precipitation (*i.e.* rain, snow, hail, etc.) fell on an average in 360 days of 1000.

First, it may be remarked that the numbers of the two series are not perhaps quite comparable, for probably the annotations from Tycho Brahe's time are not so exact as those of the new series, as an inspection of the two series seems to indicate. Accordingly, the numbers of

the new series are generally somewhat greater. From this rule there are, however, two remarkable exceptions. The month of June had in the old series a greater number of days with precipitation, rain, hail, and thunder, whereas the figures for the months July, August, September, and October were less than the present values (with only some unimportant exceptions as to hail). This indicates that the summer

TABLE V.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Probability of a day of precipitation.												
1582-97	0·290	0·250	0·310	0·250	0·210	0·360	0·370*	0·380*	0·330	0·340	0·350	0·340
1881-98	0·337	0·291	0·362	0·269	0·315	0·316	0·406	0·467	0·349	0·446	0·390	0·362
Probability of a day of rain (without snow or hail).												
1582-97	0·181	0·086	0·123	0·204	0·207	0·359	0·377	0·381	0·330	0·339	0·310	0·233
1881-98	0·172	0·135	0·193	0·214	0·298	0·312	0·402	0·463	0·343	0·420	0·325	0·227
Probability of a day of snow (with or without rain or hail).												
1582-97	0·129	0·188	0·194	0·053	0·008	0·000	0·000	0·000	0·000	0·009	0·048	0·129
1881-98	0·163	0·154	0·167	0·051	0·002	0·000	0·000	0·000	0·002	0·009	0·061	0·135
Probability of a day of hail (with or without rain or snow).												
1582-97	0·007	0·010	0·014	0·015	0·011	0·015	0·005	0·005	0·015	0·007	0·017	0·015
1881-98	0·002	0·002	0·002	0·004	0·015	0·004	0·004	0·004	0·004	0·017	0·004	0·000
Probability of a day of thunder.												
1582-97	0·000	0·003	0·000	0·003	0·028	0·053	0·043	0·034	0·015	0·000	0·000	0·000
1881-98	0·000	0·000	0·000	0·012	0·045	0·049	0·097	0·076	0·027	0·015	0·002	0·000

* Here there is some little error in Poul la Cour's calculation, as these numbers cannot be less than what corresponds to days of rain.

climate was then more continental than now. For in Scandinavia and adjacent countries the more continental climate is characterised by prevailing rain and thunder in the middle of the summer; the more maritime one, on the contrary, by prevailing rain and thunder in the latter part of the summer and autumn.

Still more striking is the difference in the number of snow days during February and March. In order to show this quite obviously I give here—

The Number of Snowy Days as a Percentage of the Number of Days of Precipitation at Uranienborg.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.
1582-1597 . .	3	14	38	45	75	63	21
1881-1898 . .	2	16	37	48	53	46	19
Difference . .	+1	−2	+1	−3	+22	+17	+2

As a greater percentage of snow days signifies a lower temperature, we see that February and March were decidedly colder 300 years ago than now, whereas the difference for the other months is nearly evanescent. By combining the number of snow days, expressed as percentages of the number of days of precipitation, for every month of the new series with the corresponding mean monthly temperature I have tried to calculate the difference between the mean temperature in Tycho Brahe's

time and the present one,[1] and hence, knowing the latter, have determined the former. The result is this:—

Mean Temperature of the Winter Half of the Year at Uranienborg.

Year.	Nov.	Dec.	Jan.	Feb.	March.	April.
	°	°	°	°	°	°
1582-1597	+3·9	+0·8	−0·9	−2·3	−0·3	+5·0
1881-1898	+3·7	+0·9	−1·1	−0·9	+0·7	+5·2
Difference	+0·2	−0·1	+0·2	−1·4	−1·0	−0·2

Thus 300 years ago February was 1°·4 C. colder than now, and March 1° C., whereas the difference for the other months amounts only to 0°·2 in the one or other direction.

Also the observations of the ice-covering in the Sound seem to indicate that the winters 300 years ago were more severe than now. For, according to the old series, a coating of solid ice occurred on an average in 10 out of 15 winters (1582-97) during about 17 days per winter, whereas in our time during the 29 winters 1870-99 it occurred during 15 winters, with an average of 16 days per winter. Drifting ice alone was observed during these 29 winters in 2 winters, with an average of 8½ days per winter, but this does not seem to have been regularly noted in the old series. Probably the difference would have been greater if the old observations had been as exact as the new ones. The latter consist of the reports from the pilot stations on the Sound, especially from Landskrona (55° 52′ N., 12° 50′ E. fr. Gr.), not far from Hven. These reports are sent every year to the Royal Swedish Direction for the Pilot Service. From the island Hven itself, as far as I know, there are no observations on the ice-covering made in our time.

As known, Brückner[2] has tried to show, in a great treatise, that the climate is subject to periodical variations of warmer and colder intervals, with a length of period amounting on an average to 34·8 years. These variations he considers to be simultaneous for the whole earth. The cause of this climatic variation is, according to Brückner, quite unknown, and the phenomenon itself, if we judge from the material worked out by him, very irregular. It is, however, interesting to examine if the difference between the climate of Hven in 1582-97 and 1881-98, as shown above, is connected with Brückner's period. Now, according to him,[3] the weather was warm, 1581-90; cold, 1591-1600; cold, 1876-90; warm, from 1891 (inclusive). We see that out of Tycho Brahe's series, according to Brückner, 8 years are warm, and 6 years 4 months cold, but out of the new series 10 years are cold and 8 years warm. In consequence, the old series ought to be warmer and the new one colder than the corresponding mean value of Brückner's period, from which would follow that the climatic variation above calculated would be still somewhat greater than the observations indicate.

Finally, we shall examine what conclusions can be drawn from the

[1] In this manner I obtained for every one of the above months a Table, showing the percentage of snow days corresponding to several values of average monthly temperature. From this Table, entering in it with the percentages in the above Table as arguments, the difference of temperature sought was obtained by means of interpolation between the temperatures corresponding to the percentages of snow days. For October no reliable result could be deduced, owing to the small number of snow days in this month.

[2] E. Brückner, *Klimaschwankungen Seit* 1700 *nebst Bemerkungen über die Klimaschwankungen der Diluvialzeit*, Wien und Olmütz, 1890.

[3] E. Brückner, *l.c.* p. 271.

regular observations of the temperature made during the last 100 to 150 years.

As to Copenhagen, Willaume-Jantzen [1] has found that during the last 110 years the winters have gradually become somewhat milder and the summers somewhat cooler, and thus a variation from a more continental to a more maritime climate, in agreement with what we have found for the last 300 years from the observations of Hven. Somewhat similar results are also to be found for Scotland, according to Buchan.[2]

TABLE VI.—MONTHLY MEANS OF THE AIR TEMPERATURE.

Months.	Haparanda with Environs, 65° 50′ N., 24° 9′ E. fr. Gr.			Stockholm Observatory, 59° 21′ N., 18° 4′ E. fr. Gr.			Lund Observatory, 55° 42′ N., 13° 12′ E. fr. Gr.			
	1802-1848 46 Years (1824 wanting).	1849-1898 50 Years.	1802-1898 96 Years.	1799-1848 50 Years.	1849-1898 50 Years.	1799-1898 100 Years.	1753-1798 46 Years.	1799-1848 50 Years.	1849-1898 50 Years.	1753-1898 146 Years.
	°	°	°	°	°	°	°	°	°	°
January .	− 12·8	− 11·7	− 12·3	− 4·3	− 3·2	− 3·7	− 2·0	− 2·2	− 1·0	− 1·8
February .	− 11·9	− 11·8	− 11·8	− 4·4	− 3·6	− 4·0	− 1·0	− 2·0	− 1·0	− 1·4
March .	− 9·1	− 8·5	− 8·8	− 1·7	− 1·8	− 1·8	0·2	0·2	0·6	0·3
April . .	− 2·7	− 2·0	− 2·3	2·9	3·1	3·0	4·9	4·9	5·0	4·9
May . .	3·5	4·0	3·8	8·7	8·7	8·7	10·3	10·7	10·3	10·4
June . .	11·4	11·8	11·6	13·9	14·3	14·1	14·8	14·9	14·9	14·9
July . .	14·4	15·0	14·7	16·8	16·9	16·8	16·9	16·9	16·5	16·8
August .	13·1	12·7	12·9	16·0	15·6	15·8	16·5	16·1	15·8	16·1
September .	7·1	7·5	7·3	11·7	11·6	11·7	12·5	12·5	12·4	12·5
October .	1·6	1·2	1·4	6·6	6·2	6·4	7·6	7·7	7·7	7·7
November .	5·7	5·4	− 5·5	1·4	1·3	1·3	2·9	3·2	2·9	3·0
December .	− 9·2	− 9·9	− 9·6	− 2·0	− 1·9	− 1·9	− 0·1	0·0	0·3	0·1
Winter .	− 11·3	− 11·1	− 11·2	− 3·6	− 2·9	− 3·2	− 1·0	− 1·4	− 0·6	− 1·0
Spring .	− 2·8	− 2·2	− 2·4	3·3	3·3	3·3	5·1	5·3	5·3	5·2
Summer .	13·0	13·2	13·1	15·6	15·6	15·6	16·1	16·0	15·7	15·9
Autumn .	1·0	1·1	1·1	6·6	6·4	6·5	7·7	7·8	7·7	7·7
Year . .	0·0	0·2	0·1	5·5	5·6	5·5	7·0	6·9	7·0	7·0

We shall now see what some of the longer Swedish series of observations indicate. They have not been completely worked out, but for Lund, Stockholm, and Haparanda I have been able, however, to calculate longer series of monthly means of the temperature. All these means I have reduced, as exactly as possible, to true daily means. The Haparanda series, being a combination of three series made at different places situated in that district of Sweden, and, partly by means of a series from Torneå, reduced to the same place, viz. Haparanda, for this and other reasons is less reliable than the two others. As to Lund, my

[1] V. Willaume-Jantzen, *Meteorologiske Observationer; Kjöbenhavn. Udgivet af det Danske Met. Institut*, Kjöbenhavn, 1896, p. 17 and following (Danish and French).

[2] A. Buchan, "The Mean Atmospheric Pressure and Temperature of the British Islands," *Journal of the Scottish Met. Soc.*, 3 ser., xiii. and xiv., 1895-96, Edinburgh and London, p. 13 and following.

mean values are calculated from the five daily means published by A. V. Tidblom,[1] and completed by the Copenhagen observations. For the sake of comparison, I give also longer series from London [2] and Paris.[3] The English and the French monthly means of the temperature are means of the daily maxima and minima.

Months.	London, City with Environs, Royal Observatory, Greenwich.				Paris, City, Montsouris, Parc de Saint Maur.		
	1763-1798 36 Years.	1799-1848 50 Years.	1849-1898 50 Years.	1763-1898 136 Years.	1806-1848 43 Years.	1849-1898 50 Years.	1806-1898 93 Years.
	°	°	°	°	°	°	°
January	3·3	2·6	3·5	3·1	1·9	2·7	2·3
February	4·7	4·1	4·4	4·3	4·3	4·0	4·1
March	5·7	5·7	5·7	5·7	6·5	6·6	6·6
April	9·1	8·6	8·9	8·8	9·9	10·5	10·2
May	12·8	12·8	12·0	12·6	14·4	13·6	14·0
June	16·2	15·5	15·7	15·8	17·1	17·2	17·2
July	17·9	17·3	17·6	17·5	18·8	18·9	18·9
August	17·9	17·1	17·2	17·3	18·5	18·5	18·5
September	15·3	14·4	14·6	14·7	15·7	15·7	15·7
October	11·2	10·5	10·2	10·6	11·3	10·9	11·1
November	6·9	6·4	6·2	6·4	6·8	6·4	6·6
December	4·7	4·1	4·2	4·2	3·7	3·3	3·7
Winter	4·2	3·6	4·0	3·9	3·3	3·3	3·4
Spring	9·2	9·0	8·9	9·0	10·3	10·2	10·3
Summer	17·3	16·6	16·8	16·9	18·1	18·2	18·2
Autumn	11·1	10·4	10·3	10·6	11·3	11·0	11·1
Year	10·5	9·9	10·0	10·1	10·7	10·7	10·7

It results from this Table that the temperature of January at all three Swedish places has risen about 1° C.; but that of August has decreased somewhat, especially at Lund, where the fall amounts to 0°·7; also July has become 0°·4 cooler there in the last 50 years. Hence the climate has varied, at least at Lund, in the manner indicated above. At Lund the four months April, June, September, and October have maintained their temperature exactly constant during the three intervals, and May and November very nearly; so that it seems legitimate to state that the spring, the beginning of summer, and the autumn have not undergone any change, which agrees with what was found for the temperature in Hven during the last 300 years. As to Stockholm, it seems that none of the ten months March to December has sensibly altered its mean temperature during the last 50 years. The numbers

[1] A. V. Tidblom, "Einige Resultate aus den met. Beob. angestellt auf der Sternwarte zu Lund in den Jahren 1741-1870," *Lunds Universitets Årsskrift*, t. xii., Lund, 1876.

[2] The years 1763-1892 according to A. Buchan, "The Temperature of London for 130 years, from 1763 to 1892," *Journal of the Scottish Met. Soc.*, 3 ser., ix., 1891; and the years 1893-98 directly from the publication of the Meteorological Office in London.

[3] The years 1806-96 according to the *Annuaire de l'Observatoire de Paris, dit Observatoire de Montsouris;* the years 1897 and 1898 from Parc de Saint Maur.

for Haparanda are, for several reasons, less reliable than those for the two other places, so that one can scarcely draw from them any other conclusion than this, that the months January to July have perhaps become a little warmer. The first half of our century was characterised by many very cold winters at all the three places in Sweden; also in London and Paris, January was then colder than afterwards. In London the summers were sensibly warmer at the end of the eighteenth century than afterwards, which agrees with the case at Lund and Copenhagen. The average temperature of the year has remained constant, with the exception of London, where it seems to have fallen a little.[1]

TABLE VII.

Months.	Haparanda, 1802–1898.				Stockholm, 1799–1898.			
	Warmest.	Year.	Coldest.	Year.	Warmest.	Year.	Coldest.	Year.
Jan.	-4·1°	1887	-22·3°	1809	1·9°	1873	-14·2°	1814
Feb.	-3·9	1822, 1891	-24·3	1871	2·7	1822	-12·8	1799
March	-1·8	1822	-15·6	1853	4·5	1822	-8·3	1888
April	1·6	1844	-7·8	1809	7·5	1803	-1·3	1812, 1829
May	9·2	1897	-4·6	1810	12·4	1889	3·2	1867
June	18·6	1810	7·0	1821	17·6	1826	10·6	1805
July	20·8	1815	11·8	1812	21·4	1855	12·9	1832
Aug.	19·4	1815	8·7	1833	20·9	1846	12·0	1864
Sept.	12·6	1815	1·8	1832	15·4	1824	8·0	1830
Oct.	6·3	1805	-4·6	1819, 1864, 1880	10·6	1821	0·7	1880
Nov.	1·1	1883	-12·2	1842	5·3	1822	-3·0	1829
Dec.	(0·5 ?)	1809	-19·6	1835	2·7	1857	-8·0	1817

Months.	Lund, 1753–1898.				London, 1763–1898.			
	Warmest.	Year.	Coldest.	Year.	Warmest.	Year.	Coldest.	Year.
Jan.	4·0°	1796	-9·5°	1809	8·4	1796	-3·4°	1795
Feb.	3·3	1779	-10·4	1845	9·9	1779	-1·7	1895
March	4·3	1846	-7·7	1845	9·4	1780	0·9	1785
April	7·8	1778	1·2	1779	13·4	1783	4·2	1837
May	14·6	1773	6·9	1843	17·5	1784	8·8	1882
June	19·2	1889	11·6	1800	19·9	1846	12·6	1814
July	(21·2)	1826	13·9	1898	23·4	1783	14·7	1767
Aug.	20·9	1834	13·0	1864	21·1	1783	14·2	1816
Sept.	16·3	1775	9·2	1812	18·7	1784	11·1	1763
Oct.	11·6	1846	(2·1 ?)	1805	15·1	1811	6·7	1817
Nov.	7·2	1772	-3·2	1773	9·9	1783	3·3	1870
Dec.	4·3	1843	-9·2	1788	8·8	1806	-1·6	1890

[1] There is also another phenomenon, exactly observed during more than 130 years, which seems to indicate that the date when spring begins, and the average temperature of this season, have not sensibly changed during this time in middle Sweden. In fact, Appelberg has calculated that the mean date of the highest vernal flood of the river Dalelfven was May 29 during the years 1765-1830, and May 28 during the years 1831-94. Ossian Appelberg,

Whether the climatic variations during the last 100 or 150 years here considered are periodic, progressive, or accidental cannot yet be decided. How considerable the accidental variations of the mean temperature of a month are, results from the following Table containing the mean temperature of the warmest and coldest months that have occurred during the interval of years in question at Haparanda, Stockholm, Lund, London, and Paris.

Months.	Paris, 1806–1898.\			
	Warmest.	Year.	Coldest.	Year.
Jan.	7·1°	1834	-4·4°	1838
Feb.	7·8	1809, 1869	-3·6	1895
March	10·2	1880	1·3	1845
April	15·1	1865	5·7	1837
May	17·7	1808, 1868	10·6	1879
June	21·2	1822	15·0	1823, 1854
July	22·7	1859	15·5	1816
Aug.	22·5	1842	15·5	1844
Sept.	19·7	1895	13·0	1807, 1877
Oct.	14·7	1831	7·3	1817
Nov.	10·6	1852	3·1	1858, 1871
Dec.	8·7	1806	-7·4	1879

Thus from the review now made of the variations of the climate in Western and North-Western Europe during the last thousand years no certain conclusion can be drawn, yet there seems to be some probability for a secular or long-period variation still going on from a more continental to a more maritime climate. If such be the case, it cannot, however, depend on the climatic variation above treated, which is produced by the variation of the obliquity of the ecliptic. For a thousand years is too short a space of time to produce any sensible variation attributable to this cause. Also the variation would then appear principally in the climate of the summer, and would be almost insensible in that of the winter, whereas, according to the observations, the inverse is the case.

As the regular measurements of rain were begun in Sweden somewhat earlier than the observations of temperature,[1] one might believe that a comparison between older and newer measurements of rain would show some variation corresponding to that of the temperature. But by a nearer inspection we find that the older measurements of the rain evidently give too low values, either owing to an unsuitable mounting of the rain gauge or to negligence in the measurement. The latter seems to have been the case at Upsala, where the results before 1836 are nearly worthless; the former at Lund, where the rain gauge till 1867 was placed on the roof of the observatory. Thus only in a far distant future will it be possible to discover by means of measurements

"Om orsakerna till vattendragens naturliga vattenvariation" ("On the Causes of the Natural Variation of the Water in Currents"), *Teknisk Tidskrift*, Stockholm, 1896 and 1897.

[1] At Lund the measurement of rainfall was begun in 1748.

of the rain climatic variations which are possibly going on with regard to this element.

8. *Conclusion—Probable variations of the climate in the future.*

The above inquiry has shown that the principal variations of the climate of the past, comprising a space of time of at least one hundred and perhaps one thousand million years, are probably due to long periodical, and perhaps also accidental, variations of the quantity of carbonic acid in the atmosphere, whereas the insolation during all this time has been nearly constant, except during the primeval epoch, when it might have been increasing somewhat.

Smaller climatic variations have occurred owing to purely astronomical causes. Among these, that due to the variation of the obliquity of the ecliptic has left obvious traces in the geological history of the earth during the post-glacial time—a space of time of about fifty thousand years. Owing to this cause, about nine thousand years ago there was a warm summer period in the Arctic and northern regions, and since that time the summers have become gradually cooler. This deterioration of our climate will continue during the next ten thousand years. The amplitude of this variation amounts to some 4° C. at 60° N.

Finally, a review of the historical reports during the last thousand years has led, with some probability, to the conclusion that a climatic variation is going on from a more continental to a more maritime climate in the north-west of Europe, especially in Scandinavia and Great Britain. The character in other respects and the cause of this variation are unknown. We cannot say if the variation is periodical, progressive, or accidental, nor how far it extends in space and time.

Now if, guided by the above results, we ask what the future climate of our earth will be, the answer runs as follows:—

The sun must at some time lose its capacity of radiating heat, owing to its continual spending of its energy. The sun, according to Helmholtz's theory, maintains its heat by contracting, and thereby becomes always hotter. My calculation[1] has given the result that its mean temperature is at present between four million and two hundred million centigrade degrees, and that the present thermometrical heat store of the sun is probably more than fifty million centigrade calories per unit of mass. Also there is probably still a considerable store of potential energy which is being gradually changed to radiant heat. But as the sun contracts, its mass becomes still more viscous, and this viscosity probably opposes a still increasing obstacle to the convectional currents which carry the interior heat to the surface. This latter, losing incessantly an enormous quantity of heat by radiation, must begin to cool as soon as, owing to this obstacle, the heat supply from the interior becomes insufficient to maintain the surface temperature. How long this will last, till this state of gradual cooling will begin, we cannot say, but probably the insolation will be sufficient still for many million years to supply the earth with radiant heat sufficient for life.

Also, as we have shown that the carbonic acid in the atmosphere is an essential condition for life on the earth, and that the carbonic acid is

[1] N. Ekholm, *Ueber den Energievorrath*, etc., cited above.

incessantly consumed by the chemical processes going on at the earth's surface and supplied principally by volcanic activity, we may ask how long this supply might be sufficient.

Now, as shown above, the volcanic activity is maintained by the secular cooling of the earth and the gradual, though periodical and partly irregular, contraction caused thereby. The volcanic activity will thus continue as long as the inner heat of the earth has not sunk sensibly below its present value. But we have found above that the cooling of the earth is extremely slow, for it takes probably about ten million years before the mean temperature of the earth has fallen 1° C. And as this temperature, if we judge from the volcanic eruptions, is still at least 2000° C., and according to the estimates of modern geophysicists even much higher, we conclude that the volcanic activity on the earth will probably continue with nearly the same intensity as at present during many hundred million years, thus probably much longer than the solar radiation. Thus we have nothing to fear for the existence of life on the earth from a future want of volcanic activity.

Yet we must expect that secular variations of the quantity of carbonic acid in the atmosphere will occur and cause climatic variations of the same kind as those revealed by geological science. Thus a future Ice Age might possibly occur. But here we find a remarkable circumstance that has hitherto been unexampled in the history of the earth. This is the influence of Man on climate.

In fact, we have seen that the present burning of pit-coal is so great that in one year it gives back to the atmosphere about $\frac{1}{1000}$ of its present store of carbonic acid. If this continues for some thousand years it will undoubtedly cause a very obvious rise of the mean temperature of the earth. Also Man will no doubt be able to increase the supply of carbonic acid also by digging of deep fountains pouring out carbonic acid. Further, it might perhaps be possible for Man to diminish or regulate the consumption of carbonic acid by protecting the weathering layers of silicates from the influence of the air and by ruling the growth of plants according to his wants and purposes. Thus it seems possible that Man will be able efficaciously to regulate the future climate of the earth and consequently prevent the arrival of a new Ice Age. By such means also the deterioration of the climate of the northern and Arctic regions, depending on the decrease of the obliquity of the ecliptic, may be counteracted. It is too early to judge of how far Man might be capable of thus regulating the future climate. But already the view of such a possibility seems to me so grand that I cannot help thinking that it will afford to Mankind hitherto unforeseen means of evolution.

During the working out of this paper I have received many valuable hints and much information from the following friends, viz.:—Dr. Gunnar Andersson, Professors Svante Arrhenius, Gerard de Geer, Dr. Axel Hamberg, Professors A. G. Högbom, G. Lagerheim, A. G. Nathorst, and R. Rubenson, for which I wish to express my sincere gratitude.

Meteorological Extremes:—Mr. R. Bentley has issued a little pamphlet entitled *Meteorological Notes applying to South Buckinghamshire.* This is a very concise index to dates, etc., of the most remarkable meteorological phenomena and extremes, which he has been able to collect for the neighbourhood of Slough. At the end of the pamphlet Mr. Bentley gives some "United Kingdom Extremes," which are so concisely stated that we reproduce them herewith.

The highest reading of the barometer occurred at 9 a.m., January 9, 1896, at Ochtertyre, Perth: 31·108 ins. (corrected to sea-level).

The lowest reading of the barometer occurred at 9.45 p.m., January 26, 1884, also at Ochtertyre, Perth: 27·332 ins. (corrected to sea-level).

[In Mr. Glaisher's ascent with Mr. Coxwell seven miles from the earth in a balloon, on September 5, 1862, the barometer fell at 37,000 feet to only 7 ins.]

The mean amplitude of the diurnal "tides" of the barometer in the United Kingdom is 0·03 in.

The highest temperature recorded was at Tonbridge on July 22, 1868: 100½° in the shade.

The lowest temperature recorded was at Blackadder, in Berwickshire, in December 1879, when the thermometer stood 23° below zero, or 55° of frost.[1]

The United Kingdom range of the thermometer has been therefore 123½°.

The mean air temperature reaches its maximum on July 16 (at Kew as late as August 8), and its minimum on January 10.

Sub-soil temperature reaches its highest in September, and its lowest in March, at a depth of 7 feet (at 25 feet, November and June).

The heaviest rainfall occurs at the Stye Head Pass in Cumberland. The greatest local rainfall was that near Windsor, September 1, 1768. The quickest rainfall was on July 17, 1890. The daily average rate at Slough is about ·068 in.

In recent times the wettest month in the south-east of England was September 1896, and the driest month February 1891. The wettest year was 1879.

The daily compass points of the wind during 51 years at Greenwich were:—

N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
2068	2366	1519	1206	1781	5436	2343	1128	781

The greatest estimated speed of the wind occurred on March 3, 1897, being recorded by a Dines pressure-tube at Rousdon Observatory, as equal to 101 miles an hour. The worst hurricane was that of November 1703.

The greatest amount of sunshine in recent years was in July 1900.

The densest fog near London was that of December 31, 1888.

The greatest thunderstorm was on August 2, 1879.

The most destructive hailstorm was on August 1, 1846.

The daily revolution of the earth (1040 miles per hour at the Equator) is about 645 miles an hour at Slough, or about 946 feet a second.

[1] The reading at Blackadder of −23° is, however, not accepted as correct. Mr. Peter Loney, an old experienced observer for the Scottish Meteorological Society at Marchmont, went to Blackadder in December 1879, and noticed that shrubs, etc., bore no traces of frost approaching −23°. The lowest *accepted* readings on record are −16° at Spring Hill Park, Kelso, December 3, 1879, and −15° at Stobo Castle, Peebles, January 17 and 18, 1881.—EDITOR.

AN IMPROVED MOUNTING FOR THE LENS AND BOWL OF THE CAMPBELL-STOKES SUNSHINE RECORDER.

By RICHARD H. CURTIS, F.R.Met.Soc.

[Read November 21, 1900.]

It seldom happens, when a new instrument is introduced to record a hitherto unobserved phenomenon, that it steps at once into the field in a state of finality; and to this rule Mr. Campbell's burning Sunshine recorder has certainly not proved an exception.

It was in the year 1853 that Mr. Campbell first commenced a regular record of sunshine in Whitehall, and four years elapsed before he was able to substitute a spherical lens of solid glass for the water-lens he first employed, and nearly twenty years more, in 1875-6, before he succeeded in getting a lens which was true in shape, and made of good glass.

Similarly the hemispherical bowl of stone, coated with a substance which would only melt at a strong heat, was used for some time before it was set aside for a similar bowl of hard wood, which could receive upon its own surface the record of six months' sunshine; and it was not until 1876 that a metal bowl, in which a strip of card could be placed, was first employed, and four years more before Sir George Stokes' modification of the card-holder, with which every one is now familiar, came into use.

One or two modifications of Sir George Stokes' original plan have been introduced since, but by far the larger number of sunshine recorders now in use are strictly of the pattern introduced by him in 1880.

In order that a Sunshine recorder may yield a reliable record it must be accurately adjusted, not only as regards its geographical position, but also as regards the relative sizes of the lens and bowl, and of the time-scale printed upon the cards employed to receive the record; and furthermore, the lens must be placed centrally in the bowl, so that whenever the sun is shining its rays may be properly focussed upon the card.

A rather wide acquaintance with these instruments has shown me that it is the exception and not the rule to find all these requirements fulfilled. The instruments are supposed to leave the hands of the makers ready for use, and a purchaser does not expect to have to examine them for a possible error in the size of the bowl,—affecting the time-scale of the record; or in the burning power of the lens,—affecting its amount. Yet in many instances—I think I shall not overstate the case if I say in the majority—they fail in one or more of these respects. Unfortunately there has not hitherto been provided a ready means of detecting an error, or of remedying it if found to exist.

Attention was called to this point in a previous paper of mine which was read at the meeting of the Society held in November 1897,[1] and I then mentioned a modification in the mounting of the bowl which I thought would secure a proper position for the lens, and I illustrated my plan by a model which I showed to the meeting.

[1] *Quarterly Journal*, vol. xxix. p. 1.

Since then I have altered the plan somewhat, and I am now able to exhibit a recorder to which my adjustments have been fitted, and which has been made by Mr. Hicks (Fig. 1).

FIG. 1.—Sunshine Recorder with improved Bowl and Mounting.

The improvement consists, first, in giving to the pedestal which carries the lens a simple sliding movement in two directions, at right angles to

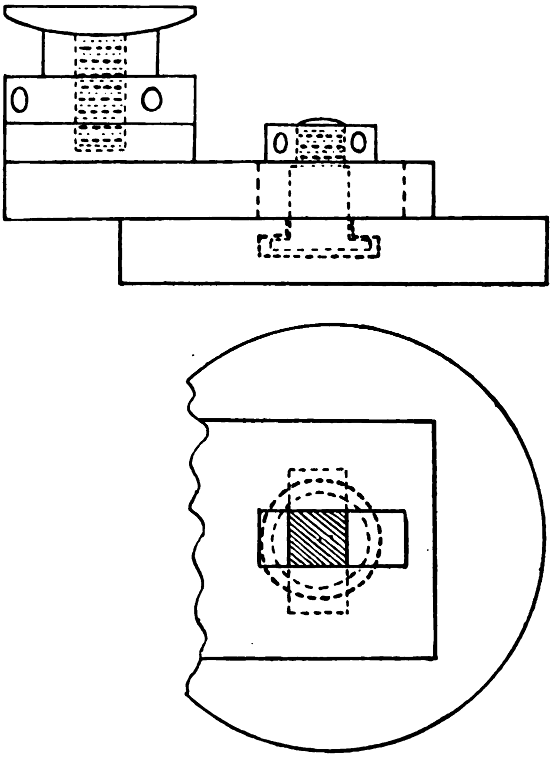

FIG. 2.—Sectional Views (Elevation and Plan) of the Adjustable Support for the Lens.

each other, and also a vertical movement; and by means of these three movements it can be quickly and accurately placed centrally in the bowl,

where it is secured by a couple of clamping screws. Secondly, the bowl itself is mounted so that it can be moved through a small arc, sufficient to accommodate it to the latitude of the station; without the rather awkward device of tilting the base, which in practice is not only a clumsy, but also a rather troublesome, adjustment to make.

It has been a point kept in view to have all these movable parts substantially made, so that the adjustment of the instrument being once made, no further trouble need be feared from slipping or weakness.

The latitude adjustment of the bowl, and the adjustment of the lens within the bowl, are of course made before the instrument is taken to the site chosen for it. All that then remains to be done is to secure for it a level base, and to place the recorder upon that base, correctly adjusted to the meridian of the station.

The adjustment of the lens in the bowl is greatly facilitated by the use of a ring of card, or, better still, one of metal, such as I described in my former paper already referred to. I employ a ring made of brass, to which I can affix a semicircle of the same radius, and this enables me to ensure getting the ring at once upon the equator of the lens.

The diagrams, Figs. 2 and 3, will make clear the way in which the adjustments of the pedestal, and of the bowl, are effected:—

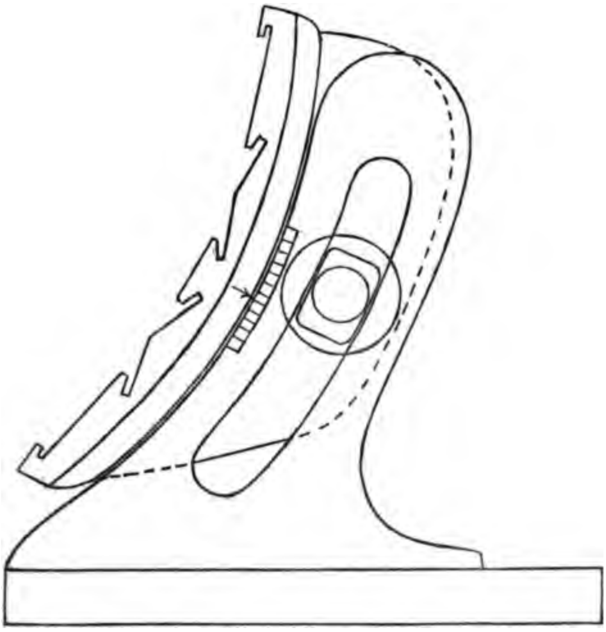

FIG. 3.—Sectional View of the Latitude Adjustment of Card-Holder, through the centre of the Bowl.

I may add that all the later instruments supplied to the Meteorological Office have been provided with these adjustments, and some of them are already in use. The additional cost is but a few shillings more than that of the old non-adjustable pattern.

DISCUSSION.

THE PRESIDENT (Dr. C. THEODORE WILLIAMS) said that thanks were due to Mr. Curtis for his improvement of the Campbell-Stokes sunshine recorder. As Mr. Curtis himself remarked, a new instrument or an alteration of an old one seldom springs at once into general use, but he hoped in this case to hear quickly of the adoption of Mr. Curtis' new method of mounting the bowl and lens.

Mr. F. C. BAYARD remarked that in very exposed positions a gale of wind was liable to upset the recorder by shifting the ball, and in one case it had been known to blow the ball out of the instrument. He inquired whether it would be possible to drill a small hole in the bottom of the ball and to insert a spike in the cup, on which the ball could be placed. This would prevent it from being moved from its position. With reference to the adjustment for latitude, he was not sure that it would be sufficient for the whole of the British Islands, as the height of the sun above the horizon varied considerably in different parts of Great Britain. The brass ring used by Mr. Curtis was a very useful one ; he had not previously seen one like it used for that purpose. It was very desirable that we should all be able to focus our balls.

Mr. W. MARRIOTT said that the question of the proper adjustment of sunshine recorders was a very troublesome one. When the instrument was first brought out many difficulties arose owing to the observers not understanding the instrument, but now its working was much better known. Mr. Curtis' improvement was a step in the right direction. He himself (Mr. Marriott) had in use a similar ring to that employed by Mr. Curtis, which had an inner measurement of over 4 inches. When placed over the ball the outer edge ran along the line on the card. Another simple test to discover if the ball was properly in the centre of the frame was to pass a sovereign between the ball and the card. If perfectly correct, the coin would just pass through all the way round. It could hardly be expected that the observers would set their instruments correctly. Some had tried, but with varying success. A great deal of trouble would be saved if the recorders were sent to Kew before being issued, and the various parts tested. In the course of his inspections he (Mr. Marriott) had discovered two seriously defective balls. Firstly, at the Royal Observatory, Greenwich, where the record was very deficient; and, secondly, at Regent's Park, where again the ball showed great deterioration. It would be noticed that both instruments were in the neighbourhood of London. The Regent's Park ball (which he exhibited to the meeting) was in great contrast to the new one in Mr. Curtis' instrument. Both the Greenwich and Regent's Park balls, which were put up by Mr. Lecky, gave good results at first, but after some years they exhibited a falling off in their records. The Regent's Park recorder, which had been in use for 15 years, had been replaced by another recorder supplied by the kindness of Mr. S. W. Silver. Both recorders had been running together for some months, and it was found that in winter when the sun was low and weak the old ball only obtained 30 per cent of the sunshine recorded by the other. In the summer, when the sun was more powerful, the percentage recorded was between 80 and 90. He thought it would be a good plan if the defective balls were thoroughly tested and examined.

Mr. R. INWARDS suggested with reference to Mr. Bayard's question that a wire be placed across the horns of the frame, which would prevent the ball being blown away.

Mr. E. MAWLEY said that he had used one of the Campbell-Stokes sunshine recorders ever since they were first adopted by the Meteorological Office, and

had often felt the want of such simple methods of adjustment as Mr. Curtis had devised. He considered they were in every way admirable. One great defect in the original pattern was the primitive method for adjusting the pedestal. He thought some equally simple and effectual plan might be arranged for securely fixing the slate base in position, for even a slight deviation in the instrument from the meridian seriously affected the direction of the trace. It was necessary that the base be firmly fixed, as some force was occasionally required to remove the card when it had become saturated or frozen.

Mr. F. J. Brodie thought that any one who had ever had anything to do with the management of sunshine recorders would greatly appreciate the value of the ingenious and very simple adjustments devised by Mr. Curtis. Hitherto the accurate adjustment of these instruments was a very difficult task, the success of which often depended to a large extent upon good fortune. Any danger of the instrument shifting after adjustment was easily prevented by carefully plastering the slate base round with cement, and thus rendering it quite immovable. The likelihood of a ball being blown from its pedestal was exceedingly remote. So far as he (Mr. Brodie) was aware, there was only one instance of the kind on record.

Mr. R. H. Curtis, replying to Mr. Bayard, said he did not think much need be feared from the strength of the wind in displacing the ball from its pedestal even in the most exposed parts of the British Islands. At Scilly, where the recorder occupied a perfectly unsheltered position, and where gales are experienced as strong as any met with in any part of the British Isles, no such thing had happened as yet. It had been mentioned that the ball had been blown off at the Great Orme's Head, but he thought the statement must have been made under a misapprehension. It certainly had been displaced, and, falling off the flat roof of the hut upon which the recorder stood, it had rolled to the bottom of the steep slope below; but he had been told on the spot that the mischievous curiosity of visitors, and not wind-force, had been the cause of the displacement. But in any case, if danger from this source was anticipated, it was the easiest thing in the world to prevent it by securing the ball to the pedestal by the use of a little Canada balsam. Such a plan would be infinitely better than boring a hole in the ball, as it would leave it perfectly uninjured. He also failed to understand Mr. Bayard's difficulty with regard to the latitude adjustment. The instrument before them had been arranged to take in any latitude from 48° to 62°, which was more than sufficient to embrace Great Britain from the Channel Islands to the Shetlands. But, if it was desired, it was quite easy to arrange it to take in any higher latitude, right up to the pole. From what he had already said, it followed that the wire across the front of the recorder suggested by Mr. Inwards was not needed, and there was also the further objection to it that it would interfere with the sun's rays. With reference to fixing the base in position when once the instrument had been correctly placed, that, of course, ought *always* to be done; for, when once properly placed, it ought not again to be moved. There were several ways of doing this, the best being determined by the exigencies of the site. If the recorder be placed on a brick or stone pedestal, a fillet of cement round the slate base will serve perfectly. If there be a flange to the pedestal, a couple of iron screw cramps, to bind the base down to the pedestal, might be best; or, if neither of these plans will serve, then wooden fillets screwed close up to the slate base, or a couple of wooden buttons to turn upon it, may do. But unless fixed in some way, tugging at a tight-fitting card might at any time put the recorder out of adjustment. As he had pointed out, a ring made of card would do perfectly well for adjusting the lens, the only condition being its accuracy; but a ring of some sort was altogether better than Mr. Marriott's sovereign. As to the verification of recorders at Kew, whilst

there are points which can and ought to be tested there, such as the quality and focal length of the glass lens, the dimensions of the bowl, and the accuracy of the adjustment at the time of testing, yet it should be remembered that after the instrument has been packed up again and sent possibly on a long railway journey, it is always possible that the adjustment may have become upset again before reaching its final destination, and, indeed, Mr. Lecky had mentioned to him a case in which this had happened. To be able to verify and, if necessary, correct the adjustment is therefore always an advantage. The question of the deterioration of the glass balls went, of course, beyond the scope of his present paper; but he might say that the two instances mentioned by Mr. Marriott, that of the Greenwich Observatory, and now the more recent one of Regent's Park, were the only ones which had come under his notice in which this optical deterioration had occurred. He had met with cases in which the colour of the glass had certainly changed, but its transparency had remained unimpaired. It was worth noting that in both the cases now in question the ball was of a very slightly bluish tint; both appeared to be of a similar quality of glass; both were similarly covered with minute reticulations which rendered them semi-opaque; and both had been supplied by Mr. Lecky and had probably a common origin. It was, perhaps, unfortunate that Mr. Lecky had obtained his glass balls from various sources, for they certainly varied in quality, and at times in other respects, such as size, also. It was to be hoped that these were the only faulty ones, but there seemed to be no doubt that the glass of which they were made was peculiarly liable to be affected by atmospheric action, at all events in an atmosphere containing so many impurities as that of London, and possibly of any large manufacturing centre. The Meteorological Office had always obtained all its balls from Messrs. Chance, and so far no indication of deterioration in any of them had come under his notice.

International Balloon Ascents and Cloud Observations.—Dr. H. H. Hildebrandsson, the Secretary of the International Meteorological Committee, has sent the following letter:—

"The Cloud Committee has expressed the wish that the Directors of Meteorological Observatories should carry out simultaneous cloud observations at epochs fixed in advance by the Aerostation Committee. After some discussion, the International Committee instructed its Secretary to inform the Directors that it would be desirable to organise observations of this character at all stations according to the above resolution. I have to request you to inform me if you desire to take part in this enterprise. In the case of your answer being in the affirmative, I have to request you to let me know the extent of the observations which you will be able to supply:

"1. Simple and direct observations of the form, amount, and direction of the clouds;

"2. Observations with nephoscopes; and

"3. Complete observations with theodolites or with photogrammeters.

"According to Prof. Hergesell, Chairman of the Committee for Aerostation, it would be of very great importance to study in this way the upper currents of the atmosphere:

"*a.* On the day preceding a simultaneous International Balloon Ascent;

"*b.* On the day of the Ascent; and

"*c.* On the day succeeding the Ascent.

"The days on which the Ascents will be made will be announced beforehand."

In a subsequent note Dr. Hildebrandsson states that the International Scientific Balloon Ascents will be made on the first Thursday of each month.

WEEKLY DEATH-RATE AND TEMPERATURE CURVES 1890 TO 1899.

By W. H. DINES, B.A., F.R.Met.Soc.

[Read November 21, 1900.]

THE ten accompanying diagrams show the weekly death-rate, and the corresponding weekly temperature for the ten years 1890 to 1899 inclusive. The death-rate is that of the thirty-three great towns of England, and is based on a population exceeding ten millions; the temperature is that of Greenwich.

There are several meteorological elements which might influence health, but of these it will probably be admitted that temperature is the most important. Any one interested in the matter can easily plot the other elements on the diagrams, and see if there is any connection, but, in my opinion, no other save fog has any appreciable effect; and by fog I mean the black artificial fog of the towns, and not the harmless white fog of the country.

The average temperature, a fifty years' mean, and also the average death-rate derived from the ten years in question, are marked upon each diagram, thus making a ready comparison with the normal conditions possible (Figs. 1-10).

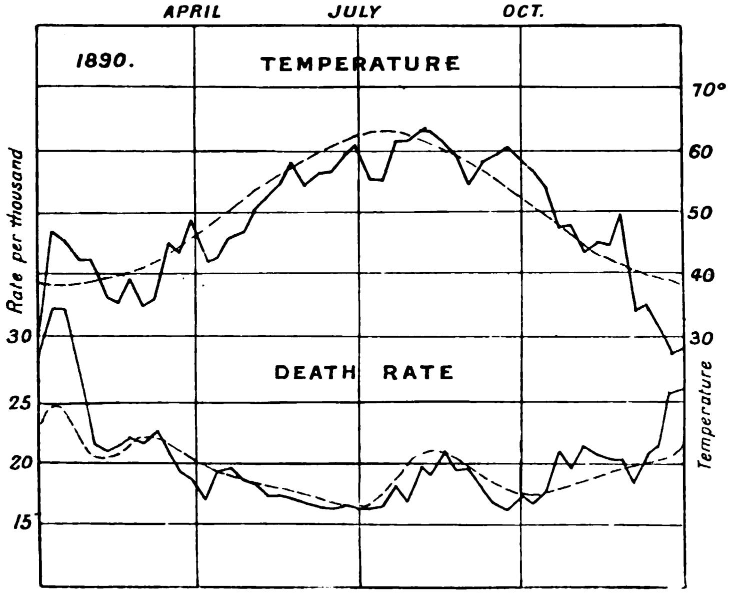

FIG. 1.

There are several points of interest about the curves, the influenza epidemics are plainly shown, notably those of January 1890, May 1891, January 1892, and March 1895. They seem to be independent of weather conditions. I am inclined to attribute the high death-rate of

January 1891 to fog, although it may be due to cold. This was the date of the long frost, but then the equally severe and long frost of January

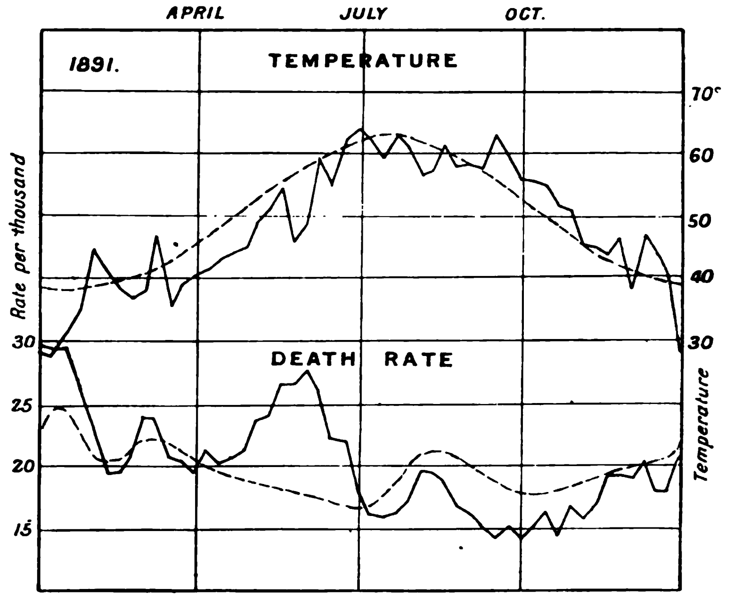

Fig. 2.

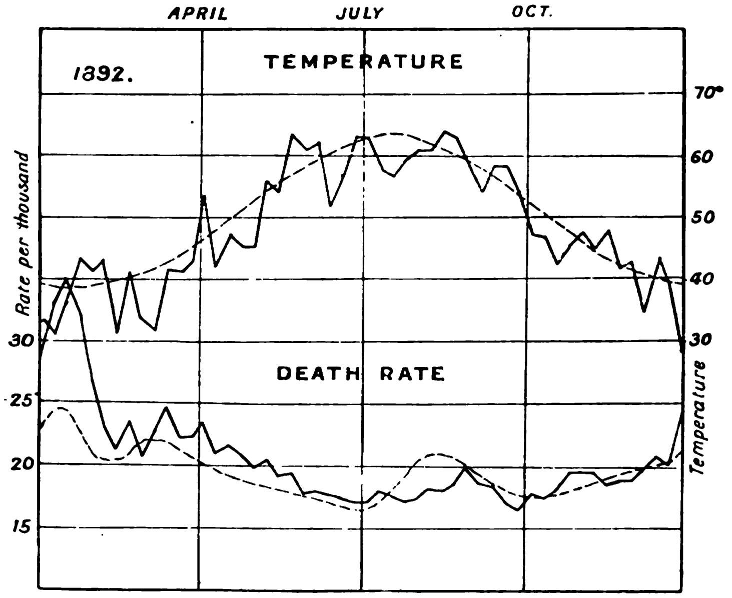

Fig. 3.

and February 1895 was accompanied by a low death-rate, the rise in which, caused by influenza, occurred just before the break-up of the frost.

In January 1891 fog was very prevalent, and the death-rate, though high in the towns, was not so in the country. In 1895 the weather conditions

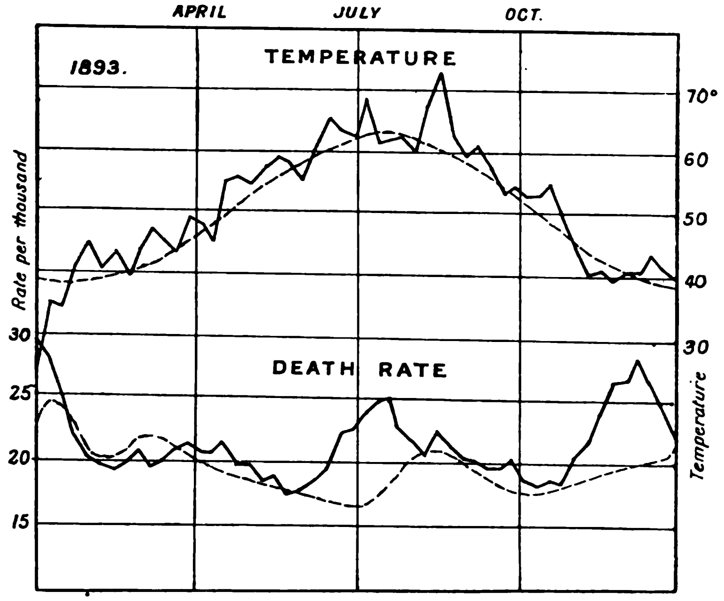

Fig. 4.

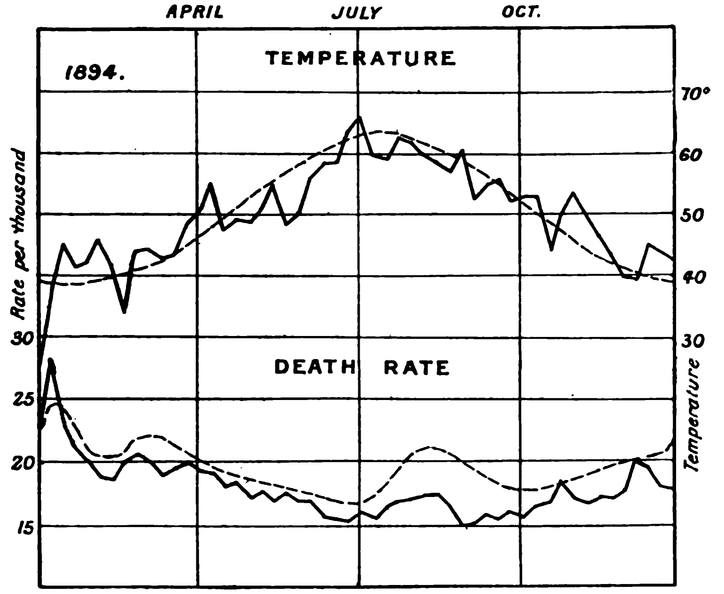

Fig. 5.

were different, and strong winds and bright sunshine prevailed during the severe weather.

The curves of the last four years of the series differ from the others, the maxima occurring in the summer. This is doubtless due to the high

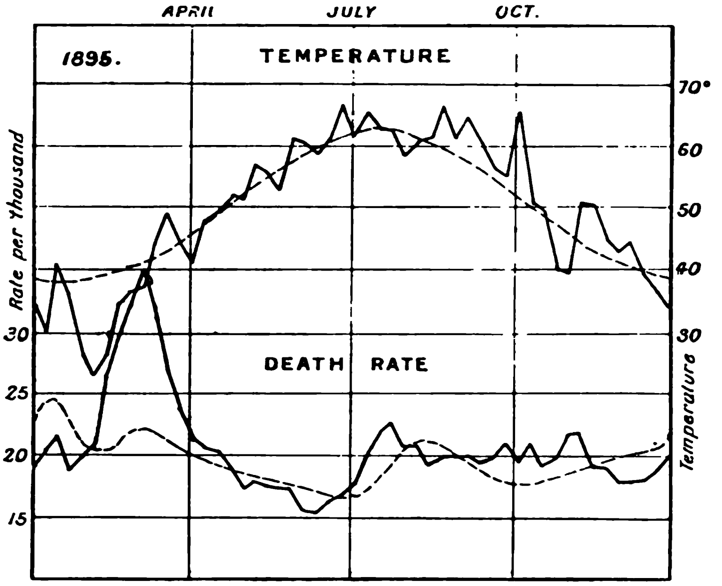

Fig. 6.

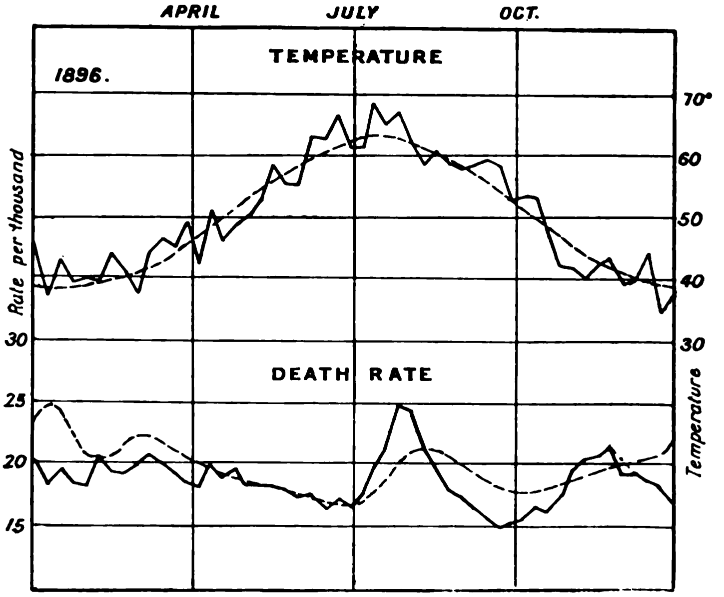

Fig. 7.

temperatures that prevailed. The ordinary summer maximum, shown by the dotted line, comes in the middle of August, the rise commencing in

the beginning of July. It will be seen that when the summer is a cold one, as in 1890, 1891, 1892, and 1894, the summer rise is delayed and is

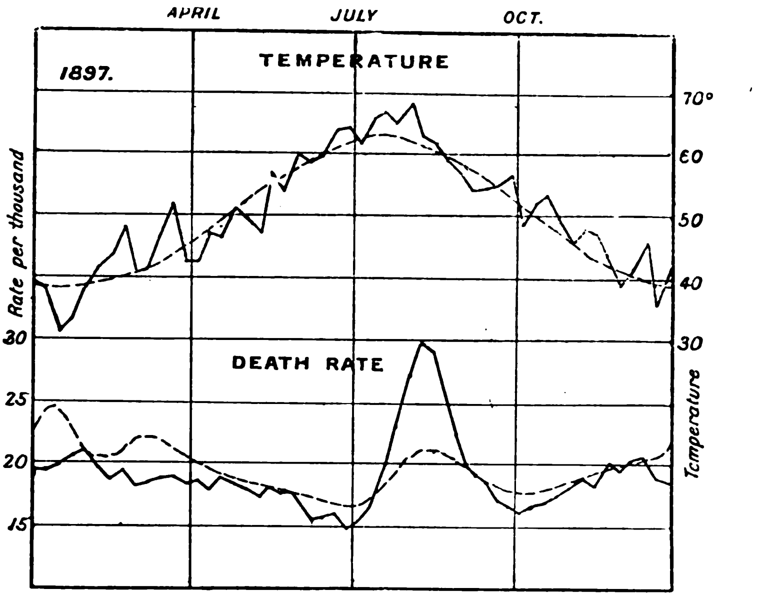

Fig. 8.

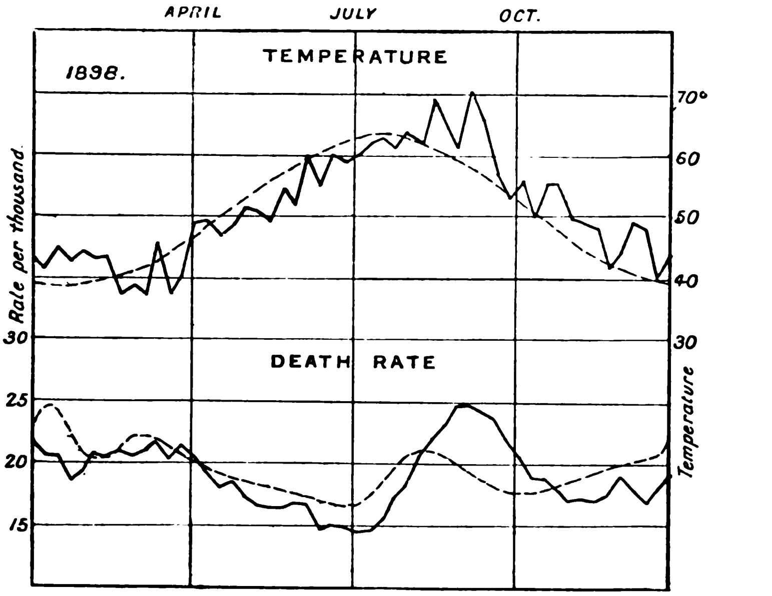

Fig. 9.

unimportant; but when the summer is a hot one, as in 1893, 1896, 1897, 1898, and 1899, it is very prominent, the crest just reaching or surpassing

the 25 per thousand level. But this is not all, in the hot summers in which the heat occurs in the early part, as in 1893 and 1895, the highest death-rate occurs before its usual time; on the other hand, in the years in which extreme heat comes towards the end of the summer, as in 1898 and 1899, the maximum comes later than usual.

Turning to the average curve there is a curious rise in the beginning of January. It is not entirely due to the influenza epidemics, for it occurs in the London average for a long series of years. Since the weather at this time is not appreciably different from what it is in December or the beginning of February, it must, I think, be due to

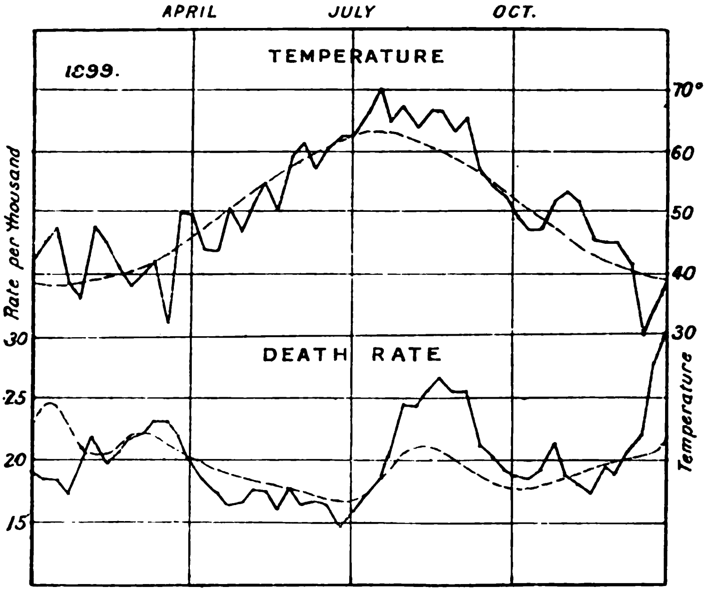

Fig. 10.

some extraneous and artificial cause. The rise in March is perhaps accidental, since the influenza epidemic of March 1895 is almost sufficient to account for it. The summer rise, from a little under 17·0 at the end of June, to a little over 21·0 at the middle of August, is a well-known phenomenon; it is partly, but not entirely, due to infant mortality from diarrhœa. It would be interesting to discover if it is more marked in countries that have a hotter summer than England.

The Englishman is certainly given to abusing his own climate, and whatever complaint he may be suffering from, he is most likely to assert that it is caused, or at least aggravated, by the weather. As a matter of fact, from the health point of view, the English climate is one of the best in the world, and this is proved by the relatively low rate (19·7) shown in these curves. It is true that there are many cities in the United States and in our own colonies that show a lower one; but the death-rate in a locality into which there is much immigration is utterly fallacious. More than half the total deaths that occur are at ages under 1 and over 60 years of age, and as neither old people nor young children

emigrate as a rule, an unduly large proportion of the population of a colony lies between the age limits, within which death is comparatively rare. Thus age and sex distribution, according to the Registrar-General, account for differences of 20 per cent between some of the English towns, and this being so, 50, or even 100 per cent, can hardly be too much to add to the death-rate of a colony into which there is much immigration. Bearing this in mind, it seems to me, after a careful study of the question, to be quite a mistake, excepting in very exceptionable circumstances, to leave England with the view of finding a healthier climate. A pleasanter climate may well be found, but the majority of the health resorts to which Englishmen resort in the winter have a higher death-rate than London has at the same season, and a far higher rate than any of the country districts of the British Isles.

DISCUSSION.

THE PRESIDENT (Dr. C. THEODORE WILLIAMS) congratulated the author on his paper, and remarked that Mr. Dines always had something to attract the attention of the Fellows.

Dr. W. G. BLACK remarked that in looking at the diagrams two things should be kept in mind, viz. the increased mortality of infants in summer, and of old people in winter, was a regular factor in statistics. These were the principal causes of the great increase of deaths shown in the paper and diagrams. In tropical countries the same thing was noticed, where European children perished in the heat and old people were comforted. The influence of personal hygiene was another important factor in the health curves. As a rule summer clothing was not discarded soon enough, and much unnecessary exposure to night air, damp and fogs, especially among the upper classes, was indulged in by going out then. It was noticeable that working men and soldiers were less frequent victims of influenza than other classes, owing to their staying in or being kept in their quarters at night. The habit of using cold water for the morning bath till well into the winter was not one to be encouraged, as it tended to create a permanent chill all day.

Mr. F. J. BRODIE was inclined to agree with Mr. Dines' somewhat novel proposition that cold winters were not necessarily unhealthy unless accompanied by fog. The severity of a cold winter may be due to one of two causes, either to the undue prevalence of anticyclonic conditions, or to a superabundance of polar winds. The three coldest winters of the past 25 years were those of 1878-9, 1890-1 and 1894-5, the mean temperature in London being in each case a fraction above or below 35°. In the season of 1878-9 the cold was due to a preponderance of winds from North and East, and fogs were less numerous than usual. Contrary, however, to Mr. Dines' proposition the winter was a very unhealthy one, the deaths in London from respiratory diseases being 24 per cent above the average. On the other hand, there was the winter of 1894-5, equally cold, and from the same cause, but with a total mortality 7 per cent below the average. The winter of 1890-1 was remarkable for the prevalence of anticyclonic conditions, accompanied by light winds and fogs, the latter being twice as numerous as the avérage for the 20 years 1871-90. In this case the winter was terribly unhealthy, the deaths from all causes being 8 per cent above the average, and these from respiratory diseases as much as 33 per cent above the normal. There appeared to be no intimate connection between influenza and weather, but there was some reason for thinking that the severity of an epidemic might be mitigated or aggravated by the atmospherical conditions

prevailing at the time. The epidemic of January 1890 created a great stir, inasmuch as it was the first event of the kind that had occurred in the memory of most people living. In reality it was one of the mildest of recent epidemics, a fact that seemed due not improbably to the favourable weather conditions prevailing at the time. January 1890 was distinguished by an almost constant succession of gales from the South-westward, and also by a large amount of bright sunshine. Both features were inimical to the growth and settlement of disease germs, the latter always flourishing most under a dull and stagnant atmosphere. With regard to the curious rise in the death-rate shown in the curves at the beginning of January he (Mr. Brodie) suggested as a possible cause the delay in registration of deaths owing to the Christmas holidays.

Mr. W. MARRIOTT said he thought that Mr. Dines would have obtained better results if he had dealt with the various causes of death rather than with the general death-rate. He would then have been able to see much more clearly the influence of temperature on the death-rate. He considered that Mr. Dines ought not to have taken the death-rate of the 33 large towns and compared that with the temperature recorded at the Royal Observatory, Greenwich. The temperature often varied in different parts of the country; and it could not be supposed that the temperature at Greenwich was always representative of that of the 33 large towns. The summer death-rate was greatly increased by infant mortality due to diarrhœa, while in winter the mortality was greatly increased by deaths due to diseases of the respiratory organs. Mr. Marriott exhibited some lantern-slides showing the relation between temperature and deaths from diarrhœa in summer and from bronchitis in winter. He also called attention to the number of deaths at various ages; and showed by a lantern-slide the high death-rate of children under one year of age. He was under the impression that Mr. Dines had only taken 52 weeks in each year, and by that means had omitted the last week in the one year in which 53 weeks occurred, which, if it had been included in his diagrams, would have shown a greater connection between temperature and the death-rate.

THE PRESIDENT (Dr. C. THEODORE WILLIAMS) remarked that the subject was a very fascinating one and had been treated in various ways by many people. Many factors had to be taken into consideration in dealing with the death-rate, besides the weather; the greater poverty occasioned by strikes, the effect of the greater consumption of fruit in a hot summer, and the result of imperfect drainage, having each to be dealt with. In cold weather there is an increase in mortality at once, and physicians have to watch their aged patients very carefully, as it is among them that the increase of mortality takes place. Most people seem to have vague ideas about influenza, to include under it all kinds of catarrh and coryza. It was a definite disease, and ran its course as regularly as typhoid or scarlet fever. It was not to be mixed up with a simple cold. He himself was a great admirer of the English climate. Its great changes no doubt caused much illness, but not a high death-rate. People left England in winter not only for the sake of their health, but to obtain more sunshine, and the greater enjoyment of open-air life. The healthiness of this country is probably due to its better sanitary conditions, for, with the possible exception of America, they were more perfect here than in any other country. Sanitary conditions have more to do with the death-rate than the weather.

Mr. BALDWIN LATHAM said that he found from experience that it would not do to take large areas in tabulating health results, owing to the great variety of conditions spread over a large area. He had frequently known heavy rain to fall in the south of England, while in the north there was very little, and *vice versâ*. In taking the 33 great towns the various causes affecting death were all smoothed down, whereas in a smaller area the influence of local

climatic conditions on the death-rate could be ascertained. In London there was an enormous number of deaths of children in summer from diarrhœa, and the death-rate did not vary much on the average in districts supplied with water from the Thames or from the chalk. In the districts supplied by the Kent Water Company from the chalk, the rise in the death-rate from diarrhœa took place a fortnight later than in places supplied by the Thames Water Companies. No doubt this was owing to the water from the former, coming as it did from deeper wells and from the chalk springs, being colder at starting through the water mains, and took longer to become heated than that from the Thames, which started at a high temperature through the water mains. In this case it would be seen that it was not temperature alone that was the cause of diarrhœa, but that it was due to the increase in temperature of our water supplies. Percolation also played an important part in influencing the death-rate, and should be taken into consideration. Many places were perfectly healthy while a drought lasted, but as soon as the rain came and percolation commenced and the accumulated impurities of the soil were washed into the water supplies, sickness and death followed. The majority of the northern towns derived their water supply from sources differing materially from those in the southern counties; and this would tend to obscure results when all the figures for every variety of supply were lumped together. He hoped that Mr. Dines would follow up his admirable paper, for which they were all much indebted to him, by working out the subject more in detail.

Mr. W. H. Dines, in reply, said that the questions raised by Dr. Black were of a medical rather than of a meteorological character, and he did not feel competent to deal with them. Still influenza was certainly a specific infectious disease, and he thought from personal observation that those who lived much in the open air and were not afraid of going out in any weather, night or day, had a much better chance of escaping it. He was glad that Mr. Brodie, who had studied the subject, agreed in general with his conclusions. The delay in registration due to Christmas could not produce the maximum in the second week in January. Were this delay the cause, there would be a sudden drop in the curve just before the rise, but there was no such drop. Since Christmas festivities had been mentioned he would say that he did think there was some connection; the large number too of children's parties and theatrical performances provided very favourable opportunities for the spread of infection, and the hot unventilated rooms in which they were held, followed by the sudden change on going out, were fruitful sources of disease. He thought that the objections raised by Dr. Williams and Mr. Marriott to some extent answered each other. Mr. Marriott suggested that a more restricted area would be better, since the meteorological conditions at Greenwich did not represent those of the other towns. This he admitted for exceptional instances, but he thought that speaking generally a hot or cold period at Greenwich was also a hot or cold period over England. However, he had preferred to take the 33 great towns, because the various factors mentioned by Dr. Williams were thus largely eliminated. A strike, or a copious supply of cheap and half-rotten fruit in a town, would doubtless influence the death-rate of that town; but things of this sort were not very likely to occur simultaneously over the whole of England, and hence the disturbances so produced would largely cancel each other out. Mr. Marriott was right in his surmise that he (Mr. Dines) had omitted the fifty-third week in one year. He fully agreed with Dr. Williams as to the greater comfort of climates in which there was more winter sunshine. How far the death-rate was a guide to the amount of illness prevalent, was a point that had often been discussed, and on it he offered no very definite opinion. Still the death-rate was very generally accepted as a standard of the general health, and particularly so by the medical officers of those health resorts which could boast

of a low rate. No doubt good sanitation helped to make a low death-rate in England, but he considered climate of more importance than sanitation, and for this reason. Fifty years ago the sanitary state of London was nothing to boast of, but the rate was never much above 25 per thousand. At the present day many towns vastly superior in the matter of sanitation to the London of 1850-1860 have a far higher death-rate than 25 per thousand. He could not agree with Mr. Latham that small districts should be taken. To obtain reliable statistical evidence it was essential to deal with large numbers. The information Mr. Latham had given with regard to the deaths from summer diarrhœa in the districts of the various water companies was very interesting.

Mr. C. Harding, in a note to the Secretary, said:—"The diagrams not being available for circulation before the Meeting, restricts the opportunity of discussion, as the diagrams practically form the essential part of this very interesting paper. I have for many years past worked up the death-rate for London and the other 'Great Towns' embodied in the Registrar-General's Returns.

"With respect to the curious rise referred to in the beginning of January, it has long occurred to me that this is due to the fact of Christmas falling in the preceding week, and consequently deferring a number of death registrations, and consequently the rise is fictitious.

"In the 4 years 1896-9 there were nearly 20,000 fewer deaths than the average in London, due doubtless, in a large measure, to the mild character of the winters, and the absence of long spells of cold, as well as to the comparative freedom from fog.

"I have gathered with some care various details from the Registrar-General's returns for each of the influenza epidemics during the last 10 years, tabulating the deaths in London for each week. In the way I have dealt with the facts to hand it is shown that there have been 10 epidemics of varying severity in the last 10 years. The several diseases of the respiratory organs have been similarly tabulated, and the deaths from all causes and from influenza tabulated for the various ages. The temperature, rainfall, sunshine, wind, and humidity have been entered for each week. The work was undertaken with the intention of communicating the results to the Society, but if the original intention is adhered to, I fear the conclusions with respect to any relation between influenza and the weather will be of a negative character. The sharpest epidemic occurred in January to March 1892. The excess of deaths from all causes in 5 weeks ending January 30 was 6534. In the 13 weeks over which the epidemic extended, the deaths from influenza numbering 2101, were 7 per cent of all causes, from bronchitis 22 per cent., and from pneumonia 8 per cent. 75 per cent of the deaths from influenza were with ages above 40. During the period of the epidemic, winds, weather, and temperature were very variable, but exceptionally low temperatures and prolonged cold occurred during the time that the epidemic was decreasing."

British Rainfall.—We learn that Mr. H. Sowerby Wallis, who was for nearly thirty years associated with the late Mr. G. J. Symons, F.R.S., and has since the latter's death carried on the British Rainfall Organisation, will, from the beginning of 1901, be joined in the work by Dr. H. R. Mill, F.R.S.E., who has resigned the librarianship of the Royal Geographical Society for that purpose.

THE SEASONAL RAINFALL OF THE BRITISH ISLES.

BY HENRY MELLISH, F.R.Met.Soc.

[Read December 19, 1900.]

THE publication by the Meteorological Council of the two series of Tables of Monthly Rainfall has placed at our disposal a vast store of information as to the monthly rainfall of these islands, which has not up to the present been very largely utilised by meteorologists. The first series was published in 1883, and contained Tables for the 15 years 1866-80 for 366 stations; the second series was published in 1897, and deals with the following decade 1881-90, as well as giving values for years previous to 1880 for a number of stations not included in the first publication. These Tables have formed the basis of the charts of mean monthly fall which appear in Bartholomew's *Atlas of Meteorology*, with a discussion of the same by Dr. Buchan. A paper by Dr. Buchan was also published in Vol. X. of the *Journal of the Scottish Meteorological Society* dealing with the monthly and annual rainfall of Scotland for the same period of 25 years, and illustrated by coloured maps.

On looking at a series of charts of the monthly rainfall of the British Isles one is struck by their general similarity. There are differences in the depths of the shading from one month to another, but the relative distribution remains the same throughout. The differences between the fall of the wet and dry districts are large, compared with the actual fall, so that though these differences are more accentuated at one time of the year than another, they always form a prominent feature of the chart. The mean rainfall of the driest month, say in the Western Highlands, is larger than that of the wettest month in a dry district, such as the Midland and Eastern Counties of England.

It follows that charts of the actual rainfall mask,—or at any rate, do not reveal—any differences that may exist in the annual rainfall curve in different districts. This was recognised by Mr. Symons at an early stage of his investigations; and in *British Rainfall* for 1867 a paper on monthly rainfall appeared from the pen of Mr. Gaster. In this paper the mean values for the decade 1850-9 at English stations were discussed; but in lieu of dealing with the average monthly depths of rain Mr. Gaster converted these amounts into percentages of the annual average at each station. He then grouped the stations in accordance with their mean annual fall, those having an annual mean between 20 and 25 ins. together, and so on, and took the means for each group. The result was to show that "at those stations where the mean annual rainfall was small, the maximum amount fell in the summer months, whilst, with the increase of the annual fall, the period of maximum fell later, until when the mean yearly rainfall exceeded 60 ins., the maximum monthly percentage was in January." A diagram was also given in which the annual curve for stations having a fall of from 15 ins. to 20 ins. is compared with that for stations with a fall of above 60 ins. The former has its minimum in February and its maximum in July; while the latter has its minimum postponed by three months to May, and its maximum by six months to January. The extremes were also found to be more decidedly marked at

the wet stations than at the dry ones. The stations were also grouped according to their longitude, Western, Central and Eastern, but no special characteristics were found to follow this grouping. It does not appear that the values were plotted on maps; possibly the stations were not sufficiently numerous. Such values as were available for the two previous decades 1830-9 and 1840-9 were also discussed and found to confirm these results.

Mr. Gaster returned to the subject in the following year 1868, and discussed the Scotch and Irish returns. The number of stations are rather small, especially in Ireland, but the conclusions arrived at were, that in Scotland, "at stations which have a small annual rainfall, the tendency is to an autumnal maximum, instead of to the summer one in England; but at stations where a large amount of rain is registered, the maximum in the winter is exhibited in a very clear manner—as in England. The time of minimum also seems to occur a little later at dry stations than in England, and perhaps to extend over a greater time (March to May); whilst in wet districts it falls in May only." "At wet stations these extremes are more marked than at comparatively dry ones." In Ireland, "at the drier stations a February minimum and early summer maximum seem to prevail; whilst in wet districts a May minimum and winter maximum are shown. The extremes are, however, not so decided as in the sister countries."

After the publication by the Meteorological Council of the Tables for the 15 years 1866-80, I converted the average monthly values for all the stations into percentages and entered these values on charts; these charts were shown at one of the Exhibitions of the Royal Meteorological Society, but no discussion of them was undertaken.

The present communication deals with those stations for which the returns are complete for the 25 years 1866-90; there are 210 of them, viz. 114 in England and Wales, 84 in Scotland, but unfortunately only 12 in Ireland. Except for the deficiency in Ireland, the distribution is fairly satisfactory, though central Wales and a good deal of the Highlands of Scotland are poorly represented, and the west coast of Scotland is largely dependent on observations at lighthouses. In lieu of dealing with individual months, the year has been divided into the four seasons, Winter including the months December to February; Spring, March to May, and so on. The percentage of the mean annual rainfall has been calculated for each season, and the values so found entered on four seasonal charts, which are submitted herewith (Figs. 1-4).

A consideration of these charts leads to the following conclusions:—

Winter.—In winter the largest percentages of rainfall are found, as a rule, at the wet stations, and the smallest at the dry ones, so that the chart of percentages for this quarter bears a strong resemblance to the chart of mean annual rainfall. This accordingly is the season in which the differences in the actual rainfalls in the different districts are the largest; and this is especially the case in January, which is the wettest month of the year in some of the very wettest districts (Fig. 1).

During these three months more than 30 per cent of the yearly total falls in Cornwall and part of Devon, in the English Lake District, and over a good deal of the west coast of Scotland, and also in the south and west of Ireland, these being the districts in which the wettest month in

the year is either December or January. The highest percentage of all, 34 per cent, is found in the Kyles of Loch Alsh ; while areas with more than 32 per cent exist to the north of the Clyde, in the English Lake District, and in the extreme south of Ireland. On the other hand, less than 24 per cent of the yearly total is recorded over the whole of the central plain and east coast of England, and parts of the east coast of Scotland, a minimum of 19 per cent being found near Ely, and minima of under 22

FIG. 1.—Winter Percentage of Rainfall.

per cent near the estuary of the Forth and in Elginshire. In Ireland a strip with less than 26 per cent extends from near Parsonstown to the north-east coast. Besides the maxima at wet stations already mentioned we find in this quarter also that the minima occur in February at a few stations on the east coast of England.

Spring.—Spring is everywhere the driest quarter, and the percentages are very uniform over the country ; rather larger in the east than in the west. The west coast of Great Britain receives rather less than 18 per cent of the annual mean, and the central plain and the east coast rather more than 20 per cent, with a local maximum of 22 per cent in Nottinghamshire.

Ireland has about 20 per cent, rather more in the south-east, rather less in the west. During this quarter the driest month of the year occurs at nearly all stations, except a few on the east coast of England, where, as already mentioned, the minimum is found in February, and at other stations in the south-west of England and on the east coasts of Scotland and Ireland, where the minimum occurs as late as June. Over the greater part of the country either March or April is the driest month (Fig. 2).

FIG. 2.—Spring Percentage of Rainfall.

Summer.—The chart for the summer months is almost exactly the reverse of the winter one; the highest percentages are now found in the dry districts, and the lowest in the wet ones, but they are on the whole slightly lower than in winter. There are now only three stations with 30 per cent of the total fall, one near Ely (where we found the minimum in winter), and two near Edinburgh. The central plain and parts of the east coast of England and Scotland receive more than 26 per cent; while the only districts with less than 20 per cent are those where we found the maximum in winter, viz. Cornwall, the English Lake District, and some parts of the west of Scotland, the minimum being rather under 18

per cent in the Kyles of Loch Alsh, where very nearly twice as much rain falls in the three winter months as in the three summer ones. In Ireland the line of 26 per cent occupies nearly the same place as in winter, but it now encloses an area of maximum, the percentage falling to about 20 on the south coast. This quarter includes months with extremes of rainfall at comparatively few stations; the districts with a minimum in June have already been mentioned; the maximum occurs

Fig. 3.—Summer Percentage of Rainfall.

in July or August at only a few places in the east of England and Scotland (Fig. 3).

Some rather curious contrasts are to be found in this season in the percentage at some of the hill stations near the borders of Cheshire and Derbyshire. Particulars of the summer and winter falls at four of these stations are given below.

Station.	Height.	Annual Rainfall.	Summer. Rainfall.	Summer. Per Cent.	Winter. Rainfall.	Winter. Per Cent.
	ft.	ins.	ins.		ins.	
Bosley Minns . . .	1210	34·10	10·14	29·7	7·10	20·8
Buxton	986	54·02	12·55	23·2	14·72	27·2
Woodhead Railway Station .	878	52·13	12·30	23·6	12·93	24·8
Dunford Bridge Reservoir .	1100	51·32	11·15	21·7	14·05	27·3

Bosley is near the Staffordshire boundary to the south of Macclesfield and to the south-west of the other three stations; though the highest of the stations given, it has a much smaller annual rainfall than the other three; during the summer months, however, it receives nearly as much rain as the others, amounting to nearly 30 per cent of its smaller annual total, while the percentage at the others is in each case less than 24. On the other hand, in winter, Bosley receives only about half the fall of the other

FIG. 4.—Autumn Percentage of Rainfall.

stations, or barely 21 per cent, while they are getting from 25 to 27 per cent of their larger total. In spring and autumn the percentages are similar throughout the district.

Autumn.—As the spring is everywhere dry, so is the autumn everywhere wet, and there is little difference in the proportion of the annual total which falls in the different districts. In Great Britain the percentage is slightly larger on the coasts, and especially on the west coasts than inland, the minimum, under 28 per cent, being found near Bedford, and also in the estuaries of the Forth and of the Tay, while the maximum, 34 per cent, occurs in the Orkneys. In Ireland the values are rather

below 28 per cent in the south-east, and above this figure in the north-west. In no district is the driest month found in this quarter, while the maximum occurs in either September, October, or November over the whole country except central and western Scotland, the south of Ireland, and a few small districts in England (Fig. 4).

In Bartholomew's *Atlas of Meteorology* four charts are given showing the distribution of the rainfall over the world in each of the four seasons. These show that Europe, except the extreme west coasts which are exposed to the west winds from the Atlantic, is within a region which receives most of its rain in summer, and has a dry climate in winter. We now see how narrow is this west coast belt of winter rains, and that the continental regime is already beginning to make itself felt in our eastern districts, and especially where these are farthest removed from the influence of the Atlantic winds.

Having now got an idea of the general distribution of the seasonal changes over the British Isles, it seems possible with the charts before us to select a limited number of stations which will represent the various types of the annual curve for more detailed study. Thirty-five stations were picked out for this purpose, the percentages of rain falling in each month of the year were calculated, and the curves plotted on squared paper. The following remarks are based chiefly on these figures, and on the two charts, showing the driest and wettest months published in Bartholomew's *Atlas of Meteorology*.

In England the driest month over the greatest part of the country is either March or April; March over the eastern and midland counties. In a few districts on the south coasts, and also in the north-eastern counties, the minimum is found in May; while in Devon and Cornwall, and in the extreme north-east, it is postponed to June. At a few stations along the east coast from the Thames to the Tyne the minimum is found in February; at most of these places this would be transferred to March if allowance were made for the different lengths of the months, but in the Durham district the February minimum is very sharply marked. This is curious, as only a little farther north, in Northumberland, the minimum does not occur till June; an examination of the curves shows that in each county there are minima in both February and June, with an intermediate maximum in March, the February minimum being most marked in Durham and the June one in Northumberland. Something of the same sort is found at Nairn, where there are minima in February and April, with an intermediate maximum in March; but in all other parts of the country the fall to, and the rise from, the annual minimum, seems to form a fairly regular curve.

In Scotland and Ireland the minimum is generally rather later than in England; nowhere except at a very few stations on the east coast as early as March, in April over the greater part of the country, in May in several districts, including some of the wettest ones, and in June at several stations near the east coasts.

The distribution of the maximum is not so simple; not only is it spread over a larger part of the year, from July to January, but in most districts the curve shows a double maximum, one of which is in the autumn, and the other either in summer in the dry districts, or in winter in the wet ones. At a few stations traces of all three maxima may be seen, as at Camden Square and East Grinstead.

The actual maximum occurs in July at comparatively few places; in England in parts of the eastern and east midland counties, and also near Durham, and in Scotland at east coast stations near the Forth and Tay. On the Moray Firth the maximum is found in August. A secondary maximum in summer is a feature of the curve over most of the central districts of England, and also in the south of Scotland and in central Ireland.

The principal maximum occurs in winter in the extreme south-west and north-west of England, over the greater part of Scotland except the north-east, and in the south of Ireland; at most places January is the wettest month, but at a few places in Scotland and the south-west of Ireland December is wetter.

Over the rest of the country the maximum occurs in the autumn; at most English stations in September or October (the earlier month in the more central districts), and in November in a few districts near the coasts. In north-east Scotland either October or November is the wettest month, while over the greater part of Ireland the maximum is in November.

As regards the relation between the amount of rain which falls in the wettest and the driest month at any station, it seems to be generally the case that the range is larger for wet stations than for dry ones; but this rule is by no means universal, and has some well-marked exceptions at some of the dry stations. Thus Ely and Nairn are among the driest stations in England and Scotland respectively, and at each the ratio between the rainfall in the wettest and the driest month is large. However, to put it generally, we may say that in wet districts rather more than twice as much rain falls in the wettest month as in the driest, and in dry districts rather less than twice.

In the accompanying diagrams (Figs. 5 and 6), the annual curves are given for a few typical stations, the values for the months January to March being repeated at the end so as to show the shape of the winter curve.

Of the English stations Bodmin has a fairly large range, with a late minimum and maxima in autumn and winter. At Camden Square and Belvoir Castle the range is very much smaller; the minimum is found in March, and traces of all three maxima are to be seen in autumn, summer, and winter, the autumn one being the most prominent. Ely shows a well-marked summer maximum, and, though a dry station, an unusually large range. At Seathwaite the winter maximum is the most prominent feature, and the minimum is spread over the three months April, May, and June. Durham shows the double minimum in February and June, the former being the lowest, and the latter being followed by a rapid rise to the maximum in July, with a second maximum in the late autumn.

Among the Scotch stations Nairn and Leith, both with a small annual rainfall, have their maximum in summer and their minimum in early spring; Waulk Glen (Renfrew) and Kyleakin (Inverness), in wetter districts, have a larger range, with well-marked winter maximum and with the minimum in April, and the early summer dry. Balfour Castle shows a type which is well marked throughout the Orkneys, very dry (under 5 per cent) in May and June, and very wet (over 12 per cent) in the last three months of the year, and with a considerable amount in

January also. The curve for Cork resembles those for the west coast of Scotland.

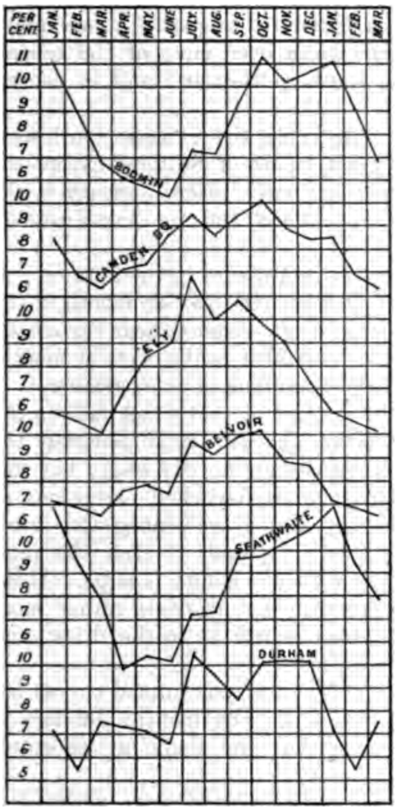

Fig. 5.—Monthly Percentages of Rainfall.

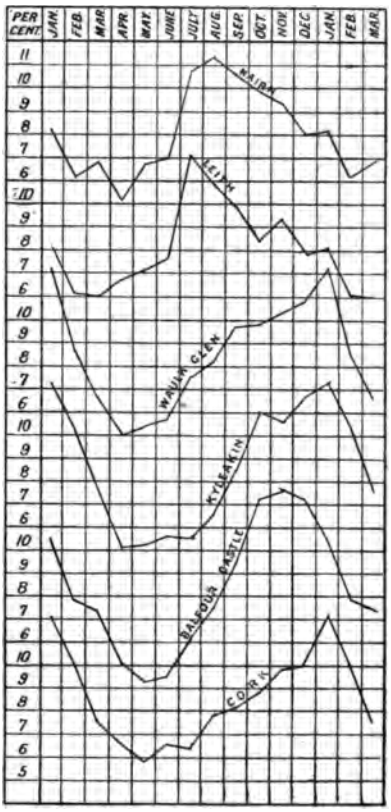

Fig. 6.—Monthly Percentages of Rainfall.

The monthly percentages of rainfall at Seathwaite for the fifty years, 1845-94 (*British Rainfall*, 1895), and those for the twenty-five years 1866-90, were as follows:—

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
50 years	11·7	9·2	7·5	4·9	5·2	5·7	7·0	8·3	8·7	10·4	10·1	11·3
25 „	11·9	9·5	7·9	4·9	5·4	5·2	7·2	7·3	9·7	9·8	10·3	10·9

It will be seen that it is only in August and September that the differences amount to as much as 1 per cent.

At the suggestion of the Council of the Society I have worked out the monthly percentages for all the stations, and these are given in the Table, pp. 88-93, as well as the seasonal percentages.

PERCENTAGES OF RAINFALL, 1866-1890.

STATION.	COUNTY.	Monthly Percentages.												Mean annual Rain-fall.	Seasonal Percentages.			
		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.		Win.	Spr.	Sum.	Aut.
ENGLAND AND WALES.		%	%	%	%	%	%	%	%	%	%	%	%	ins.	%	%	%	%
St. Austel	Cornwall	10·9	8·6	6·8	6·3	5·6	5·6	7·4	7·4	9·3	10·8	10·7	10·6	48·92	30·1	18·7	20·4	30·8
Bodmin	,,	11·1	9·0	6·8	6·1	5·7	5·3	7·3	7·2	9·3	11·3	10·2	10·7	51·88	30·8	18·6	19·8	30·8
Altarnum	,,	11·3	9·1	6·9	6·0	5·3	4·7	7·1	7·6	9·1	11·3	10·2	11·4	61·46	31·8	18·2	19·4	30·6
Plymouth	Devon	10·9	8·1	7·1	6·6	5·6	5·5	7·7	7·6	10·3	10·2	9·9	10·5	36·69	29·5	19·3	20·8	30·4
Castle Hill, South Molton	,,	9·7	7·4	6·1	5·9	6·0	5·3	8·6	8·8	9·7	12·7	9·5	10·3	45·30	27·4	18·0	22·7	31·9
Cove, Tiverton	,,	10·1	8·5	7·6	6·7	6·0	5·0	7·1	7·6	9·5	10·8	10·4	10·7	42·09	29·3	20·3	19·7	30·7
Brampford Speke	,,	10·0	8·5	7·1	7·2	6·0	5·6	7·6	7·3	9·7	11·1	9·9	10·0	35·27	28·5	20·3	20·5	30·7
Budleigh Salterton	,,	10·4	8·6	7·2	7·6	6·2	5·7	7·1	7·2	9·7	10·7	10·0	9·6	33·75	28·6	21·0	20·0	30·4
South Petherton	Somerset	9·9	8·1	6·6	7·3	6·5	6·3	8·0	7·5	10·1	10·3	10·0	9·4	29·81	27·4	20·4	21·8	30·4
Barrow Gurney Reservoir	,,	9·7	7·3	6·5	6·4	6·6	6·1	8·9	9·5	10·1	10·2	9·5	9·2	39·49	26·2	19·5	24·5	29·8
Melbury, Cerne Abbas	Dorset	10·8	8·3	6·5	6·8	5·8	6·2	7·7	8·0	10·2	10·0	10·0	9·7	35·94	28·8	19·1	21·9	30·2
Shaftesbury	,,	9·2	7·8	6·2	7·7	6·5	6·7	8·5	8·0	10·0	10·7	9·8	8·9	34·90	25·9	20·4	23·2	30·5
Chalbury, Wimborne Minster	,,	10·3	8·0	6·3	7·1	6·4	6·8	7·4	7·5	9·9	10·5	10·2	9·6	31·72	27·9	19·8	21·7	30·6
Wilton House, Salisbury	Wiltshire	10·9	8·3	6·5	6·9	6·1	6·4	7·8	7·8	9·2	10·3	10·0	9·8	32·78	29·0	19·5	22·0	29·5
Southampton	Hampshire	10·6	8·0	6·4	6·8	6·4	6·0	8·4	8·3	9·6	10·2	9·4	9·9	31·55	28·5	19·6	22·7	29·2
Strathfield Turgiss, Winchfield	,,	9·6	7·7	5·9	6·9	7·0	7·8	9·0	8·1	9·8	10·2	9·8	8·2	25·70	25·5	19·8	24·9	29·8
Osborne	Isle of Wight	10·5	8·0	6·0	6·0	6·1	6·1	7·4	8·1	10·7	11·2	10·2	9·7	28·66	28·2	18·1	21·6	32·1
Reading	Berkshire	9·6	7·5	6·2	6·7	6·8	7·7	9·4	8·7	9·8	9·8	9·6	8·2	25·86	25·3	19·7	25·8	29·2
Cookham	,,	8·9	6·8	6·2	7·0	6·9	8·2	9·7	8·8	9·9	10·0	9·1	8·5	25·99	24·2	20·1	26·7	29·0
Chilgrove, Chichester	Sussex	9·7	7·8	5·7	6·0	6·0	6·6	9·0	8·5	10·0	11·4	10·0	9·3	33·74	26·8	17·7	24·1	31·4
Petworth	,,	10·2	8·6	6·3	5·9	6·4	6·4	8·3	7·8	9·7	11·0	10·2	9·2	34·75	28·0	18·6	22·5	30·9
Glynde Place, Lewes	,,	10·0	7·6	6·2	6·4	5·7	5·9	7·4	8·3	9·3	11·9	11·0	10·3	32·60	27·9	18·3	21·6	32·2
East Grinstead	,,	9·6	8·1	6·7	6·8	6·4	6·6	8·3	7·7	9·5	10·6	10·6	9·1	32·72	26·8	19·9	22·6	30·7
High Beech, Hollington	,,	9·3	6·9	6·4	6·8	6·4	6·4	7·6	8·1	9·4	11·8	10·9	10·0	29·19	26·2	19·6	22·1	32·1
Dunsfold, Godalming	Surrey	9·7	7·8	5·6	6·4	7·0	6·9	9·5	8·0	10·2	10·5	9·8	8·6	26·66	26·1	19·0	24·4	30·5
Greenwich Observatory	London District	8·5	6·6	5·8	7·3	7·5	8·2	10·1	9·1	9·3	10·3	8·8	8·5	24·94	23·6	20·6	27·4	28·4
Kew Observatory	,,	8·5	7·0	5·9	7·4	7·3	8·2	10·0	8·6	9·8	10·3	8·7	8·3	24·19	23·8	20·6	26·8	28·8
Camden Square	,,	8·5	6·9	6·3	7·1	7·4	8·7	9·5	8·7	9·5	10·1	8·9	8·4	26·19	23·8	20·8	26·9	28·5
Enfield	,,	8·6	6·8	6·6	7·1	7·6	7·9	8·9	8·9	9·3	10·2	9·3	8·8	28·94	24·2	21·3	25·7	28·8
River Hill, Sevenoaks	Kent	9·1	7·0	6·4	6·7	6·6	7·5	8·5	8·0	9·9	10·8	10·3	9·2	28·44	25·3	19·7	24·0	31·0
Shoeburyness	Essex	8·0	6·0	6·0	6·8	7·2	7·1	8·9	8·4	10·8	11·0	10·6	9·2	20·59	23·2	20·0	24·4	32·4
Sheering, Harlow	,,	7·9	6·9	6·5	7·1	8·0	7·8	9·1	8·6	9·8	10·2	9·7	8·4	24·96	23·2	21·6	25·5	29·7
Drinkstone, Bury St. Edmunds	Suffolk	6·9	6·6	6·3	6·8	7·0	7·3	10·9	7·7	11·3	10·4	9·7	9·1	25·24	22·6	20·1	25·9	31·4
Carlton Colville	,,	7·0	6·5	6·5	6·5	6·9	6·1	10·5	8·5	10·8	10·1	11·3	9·3	25·84	22·8	19·9	25·1	32·2

Geldeston	**Norfolk**	6·5	6·5	6·5	6·2	7·0	6·7	10·9	7·8	10·8	10·8	11·2	9·1	24·27	22·1	19·7	25·4	32·8
Yarmouth	,,	7·1	6·6	6·6	6·2	6·7	6·8	10·3	7·8	10·5	10·6	11·1	9·7	27·58	23·4	19·5	24·9	32·2
Thorpe, Norwich	,,	6·8	6·4	6·7	6·8	6·8	6·9	9·8	8·4	10·8	10·8	10·8	9·0	28·53	22·2	20·3	25·1	32·4
Swaffham	,,	6·6	6·7	5·8	6·5	6·6	8·1	11·5	9·6	10·0	9·8	10·0	8·8	28·01	22·1	18·9	29·2	29·8
Hunstanton Hall	,,	6·0	6·0	5·6	6·8	7·4	8·1	10·9	9·3	11·3	10·3	9·5	8·8	23·23	20·8	19·8	28·3	31·1
Hillington	,,	7·0	6·6	6·1	6·4	6·7	7·9	10·9	10·0	10·1	9·5	9·9	8·9	27·34	22·5	19·2	28·8	29·5
Cambridge Observatory	Cambridge	6·6	6·3	6·0	7·3	8·1	9·6	10·4	9·4	9·7	9·8	8·7	8·1	23·19	21·0	21·4	29·4	28·2
Stretham, Ely	,,	6·0	5·6	5·1	6·9	8·3	9·0	11·8	10·0	10·9	9·9	9·1	7·4	22·37	19·0	20·3	30·8	29·9
Royston	Hertford	7·7	6·8	6·2	7·2	8·2	8·3	9·2	9·3	9·7	9·6	9·2	8·6	23·63	23·1	21·6	26·8	28·5
Brayfordbury, Hertford	,,	8·5	7·2	6·4	7·0	7·4	7·9	9·2	8·4	9·7	9·8	9·7	8·8	25·89	24·5	20·8	25·5	29·2
Hitchin	,,	8·3	6·8	6·0	7·2	7·8	7·5	10·5	8·6	9·6	9·8	9·6	8·3	25·10	23·4	21·0	26·6	29·0
Rothamsted, Harpenden	,,	9·0	7·1	6·0	7·3	7·6	7·7	9·6	8·4	9·5	10·1	9·3	8·4	29·01	24·5	20·9	25·7	28·9
Cowroast, Tring	,,	9·4	7·6	6·2	6·7	7·6	6·8	9·1	7·8	9·9	10·3	9·7	8·9	29·90	25·9	20·5	23·7	29·9
Cardington	Bedford	7·4	6·3	6·0	7·4	8·2	8·7	11·0	9·3	10·0	9·1	8·9	7·7	24·00	21·4	21·6	29·0	28·0
Wellingborough	Northampton	8·2	7·0	6·4	7·5	7·8	7·4	11·0	8·6	9·5	9·4	8·8	8·4	26·33	23·6	21·7	27·0	27·7
Belvoir Castle	Leicester	7·1	6·9	6·5	7·6	7·9	7·5	9·7	9·2	9·9	10·2	8·8	8·7	26·73	22·7	22·0	26·4	28·9
Thornton Reservoir, Market Bosworth	,,	7·2	6·3	5·9	6·8	7·6	8·4	9·5	10·6	10·6	10·3	8·6	8·2	27·19	21·7	20·3	28·5	29·5
Retford	Nottingham	7·1	6·4	6·7	7·1	8·7	7·8	9·9	9·8	9·3	10·6	8·3	8·3	23·43	21·8	22·5	27·5	28·2
Buxton	Derby	9·1	8·1	7·3	5·7	6·2	6·7	8·0	8·5	9·1	10·9	10·4	10·0	54·02	27·2	19·2	23·2	30·4
Woodhead Railway Station	,,	8·3	7·5	7·0	6·5	6·6	6·8	8·2	8·6	9·8	11·2	10·5	9·0	52·13	24·8	20·1	23·6	31·5
Oxford	Oxford	8·6	7·3	6·1	6·8	7·5	8·4	9·9	8·6	10·2	9·8	8·8	8·0	26·15	23·9	20·4	26·9	28·8
Witcombe Reservoir	Gloucester	9·3	7·3	6·4	7·2	7·0	7·7	9·8	8·4	10·2	9·4	9·5	7·8	30·85	24·4	20·6	25·9	29·1
Clifton	,,	9·9	7·3	6·6	6·2	6·8	6·4	9·1	9·4	9·8	9·9	9·6	9·0	35·44	26·2	19·6	24·9	29·3
Saul, Frampton-on-Severn	,,	9·8	7·8	6·1	6·9	7·2	7·1	9·0	8·6	10·4	9·0	9·6	8·5	29·06	26·1	20·2	24·7	29·0
Leamington	Warwick	8·1	6·6	5·9	6·7	7·9	7·4	10·7	9·2	10·9	9·7	9·1	7·8	26·25	22·5	20·5	27·3	29·7
Lansdowne, Evesham	Worcester	8·1	6·4	5·5	6·8	8·2	8·2	9·5	9·8	10·7	9·9	9·0	7·9	25·88	22·4	20·5	27·5	29·6
Orleton, Tenbury	,,	8·8	7·7	6·4	6·6	8·0	8·1	8·5	9·2	9·9	9·7	8·9	8·2	31·19	24·7	21·0	25·8	28·5
Ross	Hereford	10·0	7·7	6·3	6·7	7·1	7·2	9·5	8·6	10·1	9·2	9·4	8·2	30·89	25·9	20·1	25·3	28·7
Wrottesley, Wolverhampton	Stafford	7·5	6·5	5·8	6·4	8·0	8·7	9·9	10·2	10·0	10·4	8·6	8·0	28·31	22·0	20·2	28·8	29·0
Stanley Reservoir, Stoke	,,	6·8	6·1	6·5	5·9	6·9	8·3	10·0	10·6	10·4	10·6	9·4	8·5	30·78	21·4	19·3	28·9	30·4
Hengoed, Oswestry	Shropshire	9·7	7·5	6·6	6·4	7·6	6·8	7·8	8·4	9·2	10·7	9·8	9·5	36·95	26·7	20·6	23·0	29·7
Larchfield, Abergavenny	Monmouth	10·8	8·9	7·2	6·5	7·0	6·7	7·3	6·9	9·5	9·8	10·0	9·4	38·56	29·1	20·7	20·9	29·3
The Ham, Cowbridge	Glamorgan	9·9	7·0	5·9	6·0	5·2	5·6	8·7	9·5	10·6	12·2	10·3	9·1	35·57	26·0	17·1	23·8	33·1
Ely, Cardiff	,,	9·8	7·7	6·3	5·4	6·2	5·8	8·2	9·6	10·3	10·8	9·8	10·1	43·60	27·6	17·9	23·6	30·9
Lisvane, Cardiff	,,	9·9	7·8	6·4	5·8	6·4	6·1	8·5	9·7	10·1	10·2	9·4	9·7	41·80	27·4	18·6	24·3	29·7
Talavor, Llanystwmdwy	Carnarvon	9·1	6·9	6·6	5·2	5·7	6·3	7·9	9·0	10·5	11·1	11·3	10·4	36·69	26·4	17·5	23·2	32·9
Cocksidia, Carnarvon	,,	9·4	7·4	7·0	5·6	5·8	6·1	7·7	8·3	9·8	12·1	10·6	10·2	39·35	27·0	18·4	22·1	32·5
Llandudno	,,	9·1	7·0	6·4	5·8	5·8	5·8	8·5	8·5	9·9	12·0	11·2	10·0	31·28	26·1	18·0	22·8	33·1
Holyhead	Anglesea	9·8	7·5	6·6	5·5	5·5	5·8	7·0	8·0	9·4	12·5	11·3	11·1	34·45	28·4	17·6	20·8	33·2
Bosley Minns	Cheshire	6·7	5·9	5·9	5·9	7·3	8·9	10·4	10·4	11·0	10·9	8·5	8·2	34·10	20·8	19·1	29·7	30·4

PERCENTAGE OF RAINFALL, 1866-1890.—*Continued.*

Station.	County.	Monthly Percentages.												Mean annual Rain-fall.	Seasonal Percentages.			
		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.		Win.	Spr.	Sum.	Aut.
		%	%	%	%	%	%	%	%	%	%	%	%	ins.	%	%	%	%
Top Lock, Marple	Cheshire	8·3	6·4	6·9	5·8	6·5	7·7	9·5	9·4	9·9	10·7	9·6	9·3	35·74	24·0	19·2	26·6	30·2
Fairfield, Manchester	Lancashire	8·6	6·1	6·6	5·3	6·3	8·1	10·1	9·4	10·2	10·7	9·3	9·3	37·42	24·0	18·2	27·0	30·2
Belmont, Bolton	,,	8·5	6·9	7·0	5·1	5·4	6·7	9·6	9·7	10·2	11·1	9·9	9·9	59·05	25·3	17·5	26·0	31·2
Blackstone Edge	,,	9·0	7·9	7·1	5·8	5·9	7·4	8·9	8·7	9·8	11·2	9·6	8·7	42·54	25·6	18·8	25·0	30·6
Stonyhurst College	,,	8·7	7·1	7·2	5·0	5·5	6·8	9·5	9·8	10·4	10·7	9·7	9·6	47·92	25·4	17·7	26·1	30·8
Downham Hall, Clitheroe	,,	8·9	7·3	7·2	5·1	5·8	6·4	9·2	9·8	10·0	10·4	10·0	9·9	43·04	26·1	18·1	25·4	30·4
Rufford	,,	8·4	6·3	6·6	5·3	6·0	6·8	10·2	9·5	10·6	11·7	9·6	9·0	34·30	23·7	17·9	26·5	31·9
South Shore, Blackpool	,,	8·9	6·7	6·6	5·0	5·7	6·1	9·5	8·9	11·0	12·0	10·3	9·3	34·31	24·9	17·3	24·5	33·3
Southfield, Lancaster	,,	9·4	6·7	6·8	4·8	5·7	7·0	9·5	9·7	10·5	10·8	9·8	9·3	40·41	25·4	17·3	26·2	31·1
Holker, Cartmel	,,	9·7	6·9	6·9	5·1	5·4	6·1	9·0	9·5	10·6	11·2	10·0	9·6	44·22	26·2	17·4	24·6	31·8
Monk Coniston	,,	10·9	9·2	7·8	4·6	4·9	4·9	7·3	7·8	9·8	11·0	10·7	11·1	78·68	31·2	17·3	20·0	31·5
Redmires, Sheffield	York, W.R.	7·9	7·2	7·3	7·0	7·1	7·3	8·4	8·4	9·1	11·6	9·7	9·0	42·12	24·1	21·4	24·1	30·4
Magdalens, Doncaster	,,	7·3	5·9	6·9	6·8	7·7	8·3	10·9	9·4	9·5	10·4	8·1	8·8	26·10	22·0	21·4	28·6	28·0
Dunford Bridge Reservoir	,,	9·1	8·4	7·6	6·0	6·3	6·4	7·6	7·7	9·3	11·6	10·2	9·8	51·32	27·3	19·9	21·7	31·1
Holbeck, Leeds	,,	8·0	6·6	7·0	7·1	7·0	7·6	10·3	8·5	9·6	10·3	8·8	9·2	26·98	23·8	21·1	26·4	28·7
Ribston, Wetherby	,,	7·4	6·9	7·3	7·4	6·9	8·0	9·5	9·1	9·9	10·5	8·4	8·7	28·00	23·0	21·6	26·6	28·8
Arncliff	,,	11·1	8·1	7·9	5·5	5·4	5·7	8·1	8·2	9·1	10·3	10·5	10·1	61·41	29·3	18·8	22·0	29·9
Kirkby Stephen	Westmorland	11·2	7·8	7·0	5·3	5·5	6·3	8·5	8·5	9·5	10·3	9·9	10·2	39·95	29·2	17·8	23·3	29·7
Keswick	Cumberland	12·0	9·1	6·8	4·9	4·9	4·7	7·3	8·0	9·9	10·7	10·8	10·9	60·33	32·0	16·6	20·0	31·4
Seathwaite	,,	11·9	9·5	7·9	4·9	5·4	5·2	7·2	7·3	9·7	9·8	10·3	10·9	136·04	32·3	18·2	19·7	29·8
Whinfell Hall, Cockermouth	,,	10·7	8·4	6·9	4·9	5·6	5·8	7·8	8·4	10·9	10·8	10·2	9·6	52·54	28·7	17·4	22·0	31·9
Carlisle Cemetery	,,	8·9	6.1	6·1	5·7	6·1	6·9	11·4	11·5	10·3	9·7	9·3	8·0	30·28	23·0	17·9	29·8	29·3
Wytham-on-the-Hill	Lincoln	6·5	6·6	5·2	8·0	8·3	8·4	10·8	9·6	10·6	9·7	8·6	7·7	23·52	20·8	21·5	28·8	28·9
Pode Hole, Spalding	,,	7·0	6·4	5·6	7·8	8·1	8·2	11·0	9·7	9·8	9·5	8·5	8·4	25·19	21·8	21·5	28·9	27·8
Stubton	,,	6·8	6·9	6·3	7·6	8·4	7·9	9·3	9·7	9·7	10·3	8·6	8·5	26·08	22·2	22·3	26·9	28·6
Lincoln	,,	6·9	6·7	6·1	7·2	7·6	8·4	9·7	10·8	9·9	10·0	8·5	8·2	23·63	21·8	20·9	28·9	28·4
Louth	,,	7·1	6·9	6·6	6·4	7·1	7·3	9·4	9·9	10·5	10·4	9·4	9·0	29·49	23·0	20·1	26·6	30·3
Brigg	,,	6·2	6·2	6·4	6·7	6·9	8·0	10·2	10·6	10·6	11·0	8·7	8·5	22·45	20·9	20·0	28·8	30·3
Grimsby	,,	6·6	6·5	6·8	6·8	7·2	6·8	10·0	9·5	9·8	11·2	9·8	9·0	23·23	22·1	20·8	26·3	30·8
New Holland	,,	6·9	6·5	6·7	6·6	7·3	7·9	9·3	9·7	10·0	10·7	9·4	9·0	23·57	22·4	20·6	26·9	30·1
Warter, Pocklington	York, E.R.	6·9	6·8	7·5	6·9	7·0	6·9	9·8	9·2	9·8	10·6	9·2	9·4	30·98	23·1	21·4	25·9	29·6
Scarborough	York, N.R.	6·8	6·0	6·6	6·8	6·8	6·7	9·8	9·4	9·8	10·8	10·6	9·9	28·50	22·7	20·2	25·9	31·2
Whitby	,,	7·1	6·0	7·0	6·8	6·9	7·4	9·8	9·0	9·2	10·4	9·9	10·5	26·63	23·6	20·7	26·2	29·5
Durham Observatory	Durham	7·1	5·5	7·5	7·3	7·1	6·6	10·3	9·6	8·5	10·1	10·2	10·2	28·89	22·8	21·9	26·5	28·8

Seaham	,,	6·5	5·4	7·3	7·1	7·3	6·7	11·0	9·9	9·3	9·6	10·0	9·9	28·02	21·8	21·7	27·6	28·9
Hallington	Northumberland	7·9	6·9	7·7	6·8	6·4	6·0	9·1	9·2	9·3	9·6	10·1	11·0	31·35	25·8	20·9	24·3	29·0
North Shields	,,	6·8	5·8	7·1	6·8	6·5	6·5	10·3	11·1	9·6	9·7	9·9	9·9	26·75	22·5	20·4	27·9	29·2
Howick Hall	,,	7·0	6·4	7·2	6·4	6·7	6·2	10·0	9·7	10·3	9·7	10·1	10·3	28·44	23·7	20·3	25·9	30·1
Lilburn Tower, Ilderton	,,	6·4	6·7	7·7	7·2	6·7	5·9	9·4	9·4	9·5	9·8	11·2	10·1	30·04	23·2	21·6	24·7	30·5
Point of Ayre Lighthouse	Isle of Man	9·2	7·6	6·6	5·5	6·1	5·4	8·3	10·3	8·8	10·8	10·9	10·5	26·72	27·3	18·2	24·0	30·5
SCOTLAND.																		
Corsewall Lighthouse	Wigtown	10·8	8·6	7·2	6·0	5·9	5·6	7·7	8·7	9·4	9·5	11·2	9·4	34·63	28·8	19·1	22·0	30·1
Mull of Galloway Lighthouse	,,	10·0	8·1	5·8	5·3	6·3	5·5	8·1	9·6	9·9	10·2	11·2	10·0	26·81	28·1	17·4	23·2	31·3
Drumlanrig	Dumfries	13·1	9·5	6·9	5·5	5·2	5·6	8·1	7·6	9·5	9·5	10·4	9·1	47·70	31·7	17·6	21·3	29·4
Auchinlee	Ayr	11·0	7·5	6·7	4·9	5·8	5·8	7·9	9·2	10·5	10·0	10·2	10·5	35·95	29·0	17·4	22·9	30·7
Ardrossan	,,	11·0	7·9	6·3	5·6	6·1	6·5	7·5	9·8	9·5	10·0	10·1	9·7	38·55	28·6	18·0	23·8	29·6
North Craig, Kilmarnock	,,	10·5	7·6	6·2	5·1	5·4	6·4	8·6	9·7	10·6	10·2	10·0	9·7	38·94	27·8	16·7	24·7	30·8
Black Loch	Renfrew	11·5	7·9	7·0	5·1	5·8	6·1	7·2	8·6	9·9	9·9	10·7	10·3	57·78	29·7	17·9	21·9	30·5
Waulk Glen	,,	12·2	8·6	6·7	5·2	5·4	5·6	7·5	8·2	9·7	9·8	10·3	10·8	47·00	31·6	17·3	21·3	29·8
Springside	,,	11·3	8·5	6·9	5·3	5·4	6·2	7·1	8·8	10·1	10·0	10·2	10·2	56·77	30·0	17·6	22·1	30·3
Ryat Lynn Reservoir	,,	12·2	8·5	6·8	5·2	5·6	5·7	7·5	8·2	9·7	9·6	10·2	10·8	48·29	31·5	17·6	21·4	29·5
Middleton	,,	11·9	8·6	6·9	5·2	5·6	5·8	7·6	8·5	9·9	9·8	9·9	10·3	55·14	30·8	17·7	21·9	29·6
Greenock	,,	12·6	9·2	7·0	5·3	5·4	5·4	6·6	7·9	9·3	10·0	10·0	11·3	62·22	33·1	17·7	19·9	29·3
Arrochar	Dumbarton	11·6	9·7	7·9	5·5	5·2	5·8	6·8	7·4	8·5	10·3	9·7	11·6	85·16	32·9	18·6	20·0	28·5
Mull of Cantyre Lighthouse	Argyll and Bute	8·9	8·3	6·8	6·8	5·9	7·5	8·6	9·5	8·8	9·1	10·3	9·5	40·83	26·7	19·5	25·6	28·2
Devaar Lighthouse	,,	11·7	8·7	6·9	5·2	5·0	5·6	6·8	7·9	8·7	10·9	11·7	10·9	44·13	31·3	17·1	20·3	31·3
Pladda Lighthouse	,,	10·0	8·4	6·9	5·4	5·6	6·0	7·9	9·9	10·0	10·3	10·1	9·5	40·11	27·9	17·9	23·8	30·4
Rothesay	,,	10·7	8·1	7·0	5·3	5·5	6·5	8·0	8·9	9·7	10·0	10·3	10·0	48·96	28·8	17·8	23·4	30·0
Rhinns of Islay Lighthouse	,,	9·9	7·8	6·4	4·8	5·3	6·5	7·8	9·3	9·6	10·8	11·3	10·5	35·03	28·2	16·5	23·6	31·7
Eallabus, Islay	,,	10·5	8·2	6·9	5·1	4·6	5·9	6·7	8·5	9·8	11·2	11·4	11·2	49·12	29·9	16·6	21·1	32·4
Kilmory	,,	12·2	8·4	7·4	4·9	4·9	5·8	6·9	7·9	9·3	10·5	10·7	11·1	61·63	31·7	17·2	20·6	30·5
Calton Mor	,,	10·6	8·0	6·9	4·8	4·8	6·5	7·9	8·5	10·1	11·0	10·4	10·5	53·27	29·1	16·5	22·9	31·5
Lismore Lighthouse	,,	11·2	8·9	6·8	5·1	5·9	6·2	8·1	8·7	8·7	10·1	10·2	10·1	43·07	30·2	17·8	23·0	29·0
Airds, Appin	,,	10·6	8·4	6·6	4·8	5·3	6·7	8·1	8·9	9·4	10·1	10·4	10·7	57·13	29·7	16·7	23·7	29·9
Corran Lighthouse	,,	12·6	9·7	8·1	4·8	4·5	5·6	6·9	7·8	8·5	9·9	10·2	11·4	77·29	33·7	17·4	20·3	28·6
Ardnamurchan Lighthouse	,,	10·9	8·5	6·7	4·9	5·1	5·9	7·3	7·9	9·5	11·8	11·0	10·5	43·54	29·9	16·7	21·1	32·3
Bothwell Castle	Lanark	10·4	7·4	5·9	5·3	6·5	6·7	10·4	10·2	9·7	9·8	9·6	9·1	28·85	26·9	17·7	27·3	28·1
Glasgow Observatory	,,	10·5	8·3	6·2	5·5	5·9	6·7	8·8	9·4	9·8	9·4	9·4	10·1	40·21	28·9	17·6	24·9	28·6
Rockville	Linlithgow	10·6	7·6	6·7	6·1	6·6	6·0	9·5	10·2	9·2	9·0	9·3	9·2	32·01	27·4	19·4	25·7	27·5
Mugdock Reservoir, Strathblane	Stirling	11·5	9·1	6·9	5·2	5·7	6·0	8·2	8·5	9·4	9·2	9·9	10·4	48·02	31·0	17·8	22·7	28·5
Kerse, Falkirk	,,	11·3	7·8	6·4	5·4	6·1	5·9	9·1	9·4	9·1	9·3	9·8	10·4	31·57	29·5	17·9	24·4	28·2
Polmaise	,,	11·9	8·1	6·6	5·4	6·0	6·3	8·2	9·1	8·5	9·9	9·9	10·1	36·67	30·1	18·0	23·6	28·3
Head of Duchray Valley	,,	11·1	7·6	6·5	5·1	6·3	6·8	7·3	9·8	9·7	10·6	9·5	9·7	82·09	28·4	17·9	23·9	29·8

PERCENTAGE OF RAINFALL, 1866-1890.—*Continued.*

STATION.	COUNTY.	Monthly Percentages.												Mean annual Rain-fall.	Seasonal Percentages.			
		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.		Win.	Spr.	Sum.	Aut.
		%	%	%	%	%	%	%	%	%	%	%	%	ins.	%	%	%	%
West Grange, Culross	Perth	9·5	7·2	6·3	5·7	6·3	6·7	10·0	10·8	8·8	9·6	10·0	9·1	34·89	25·8	18·3	27·5	28·4
Kippenross	,,	12·0	7·9	6·6	4·9	5·2	5·7	7·9	9·2	9·7	10·2	10·0	10·7	34·11	30·6	16·7	22·8	29·9
Lanrick Castle	,,	12·0	8·3	6·9	5·3	5·6	6·3	7·7	9·3	9·0	9·6	9·7	10·3	46·59	30·6	17·8	23·3	28·3
Aberfoyle	,,	12·5	8·7	6·8	5·3	5·7	6·0	7·1	8·5	9·0	9·8	9·6	11·0	57·34	32·2	17·8	21·6	28·4
Loch Dhu	,,	12·8	9·2	7·2	5·4	5·7	5·6	6·4	7·6	8·6	10·1	10·2	11·2	80·70	33·2	18·3	19·6	28·9
Tunnel Hill Top, Loch Katrine	,,	11·9	9·6	7·3	5·2	5·6	5·8	6·7	7·5	8·6	10·6	10·2	11·0	75·26	32·5	18·1	20·0	29·4
Glengyle	,,	12·0	8·9	6·7	5·5	5·5	5·9	6·5	9·0	8·7	10·2	10·1	11·0	92·78	31·9	17·7	21·4	29·0
Stronvar	,,	13·3	9·6	7·8	5·3	5·4	5·2	6·4	7·0	8·4	10·3	10·1	11·2	76·35	34·1	18·5	18·6	28·8
Culloden House	Inverness	8·6	6·5	6·6	5·2	6·5	6·4	11·0	10·8	10·9	9·0	10·0	7·9	24·63	23·0	18·3	28·2	30·5
Kyleakin Lighthouse	,,	12·3	10·4	7·6	5·1	5·2	5·6	5·5	6·5	8·5	11·0	10·6	11·7	71·40	34·4	17·9	17·6	30·1
Rona Lighthouse	,,	11·2	8·9	7·0	4·8	5·0	5·8	6·4	8·1	9·0	12·6	10·7	10·5	42·53	30·6	16·8	20·3	32·3
Ardross Castle	Ross	9·4	7·7	7·3	6·4	6·6	6·6	8·0	8·5	9·2	10·8	10·2	9·3	37·77	26·4	20·3	23·1	30·2
Barra Head Lighthouse	Hebrides	11·6	7·7	6·9	5·1	5·4	6·5	8·3	9·1	9·0	10·6	9·9	9·9	30·00	29·2	17·4	23·9	29·5
Island Glass Lighthouse	,,	11·1	8·8	7·2	5·4	4·8	6·0	7·4	8·0	8·8	10·8	10·6	11·1	41·98	31·0	17·4	21·4	30·2
Butt of Lewis Lighthouse	,,	11·4	8·9	7·8	5·5	5·1	5·3	6·7	8·2	8·4	10·9	10·6	11·2	38·80	31·5	18·4	20·2	29·9
Dunrobin Castle	Sutherland	8·4	8·0	7·3	5·8	5·6	6·7	8·0	8·5	8·7	10·8	11·2	11·0	30·60	27·4	18·7	23·2	30·7
Scourie	,,	9·6	7·8	7·7	5·0	4·8	5·6	7·8	8·3	8·4	12·2	11·0	11·8	42·51	29·2	17·5	21·7	31·6
Cape Wrath Lighthouse	,,	10·0	7·6	6·1	4·7	5·4	6·0	8·1	9·5	9·9	11·4	10·8	10·5	39·82	28·1	16·2	23·6	32·1
Holborn Head Lighthouse	Caithness	8·3	7·4	7·2	6·1	5·3	5·4	7·6	9·0	8·8	11·8	11·3	11·8	29·66	27·5	18·6	22·0	31·9
Pentland Skerries Lighthouse	Orkney	8·8	7·6	7·2	5·8	5·6	5·6	7·3	9·0	9·2	11·2	11·9	10·8	25·45	27·2	18·6	21·9	32·3
Cantick Head Lighthouse	,,	10·2	8·0	7·5	5·8	4·4	4·9	6·9	8·0	8·6	11·2	12·5	12·0	38·25	30·2	17·7	19·8	32·3
Balfour Castle	,,	10·5	7·9	7·4	5·1	4·3	4·5	6·2	7·5	9·5	12·2	12·7	12·2	32·31	30·6	16·8	18·2	34·4
Hoy Low Lighthouse	,,	9·4	7·9	7·3	5·5	5·0	5·1	6·8	8·3	9·0	11·5	12·7	11·5	32·33	28·8	17·8	20·2	33·2
Start Point Lighthouse	,,	10·5	8·2	8·1	5·8	4·5	4·3	6·9	8·6	9·3	11·2	11·2	11·4	33·05	30·1	18·4	19·8	31·7
North Ronaldshay Lighthouse	,,	10·0	8·1	7·9	5·6	4·8	4·4	7·3	8·2	8·6	11·2	12·4	11·5	29·64	29·6	18·3	19·9	32·2
Bressay Lighthouse	Shetland	10·7	9·2	8·2	5·4	4·3	4·2	6·3	8·9	8·5	11·2	11·2	11·9	36·79	31·8	17·9	19·4	30·9
The Flatt, New Castleton	Roxburgh	11·6	8·6	6·9	5·1	5·4	5·7	8·4	8·5	10·0	9·9	10·0	9·9	47·30	30·1	17·4	22·6	29·9
Wolfelee	,,	11·3	8·3	7·3	6·1	6·3	5·7	8·3	8·2	8·3	9·5	10·4	10·3	40·29	29·9	19·7	22·2	28·2
Springwood Park, Kelso	,,	7·5	6·6	6·7	6·5	6·3	7·3	11·2	10·9	9·3	9·0	9·7	9·0	26·58	23·1	19·5	29·4	28·0
Wooplaw	,,	8·3	7·1	6·9	7·1	6·5	7·0	9·7	10·0	9·5	9·3	10·0	8·6	32·42	24·0	20·5	26·7	28·8
Glenrath	Peebles	10·6	8·0	7·6	6·3	5·7	5·9	8·5	8·0	8·9	9·5	11·0	10·0	40·84	28·6	19·6	22·4	29·4
Marchmont	Berwick	7·2	6·3	7·2	7·1	6·7	7·1	10·3	10·0	9·3	9·5	10·9	8·4	36·66	21·9	21·0	27·4	29·7
Smeaton House, Prestonkirk	Haddington	7·4	5·9	6·1	6·9	6·7	7·4	12·6	10·8	10·0	8·7	10·0	7·5	25·66	20·8	19·7	30·8	28·7
Glencorse Reservoir	Edinburgh	10·2	7·2	7·5	6·9	6·9	5·6	10·0	9·6	9·0	8·7	9·9	8·5	39·86	25·9	21·3	25·2	27·6

Fernielaw, Colinton	,,	10·1	7·4	7·2	6·9	6·8	6·2	10·5	9·6	9·0	7·8	9·3	9·2	34·53	26·7	20·9	26·3	26·1
Charlotte Square, Edinburgh	,,	8·5	6·8	6·1	6·7	7·3	7·1	11·4	11·2	9·8	8·0	9·2	7·9	26·72	23·2	20·1	29·7	27·0
Leith	,,	8·1	6·1	6·0	6·7	7·1	7·6	12·1	10·8	9·9	8·4	9·3	7·9	23·60	22·1	19·8	30·5	27·6
Dollar	Clackmannan	10·3	8·4	6·7	6·1	6·4	6·3	9·1	9·5	8·7	9·8	9·4	9·3	43·38	28·0	19·2	24·9	27·9
Loch Leven Sluice	Fife and Kinross	10·0	7·9	6·8	6·2	6·5	6·2	8·7	9·6	8·8	9·7	9·9	9·7	36·17	27·6	19·5	24·5	28·4
Mountquhanie	,,	8·8	6·5	6·5	6·2	6·5	6·7	9·9	11·4	10·4	8·5	9·3	9·3	29·23	24·6	19·2	28·0	28·2
Eastern Necropolis, Dundee	Forfar	8·5	7·4	6·8	6·9	6·2	6·8	10·5	9·9	9·9	8·8	9·2	9·1	29·18	25·0	19·9	27·2	27·9
Craigton Reservoir	,,	9·0	8·0	7·2	6·9	6·4	6·5	9·8	10·3	9·3	8·9	8·8	8·9	38·16	25·9	20·5	26·6	27·0
Arbroath	,,	8·8	7·1	6·8	6·7	6·6	7·0	10·4	10·0	9·4	8·9	9·1	9·2	28·20	25·1	20·1	27·4	27·4
Montrose	,,	7·3	7·1	6·3	7·1	6·0	6·7	10·8	10·5	10·1	9·6	9·2	9·3	30·19	23·7	19·4	28·0	28·9
Fettercairn	Kincardine	8·9	8·4	7·0	6·9	6·1	6·0	8·8	9·1	9·0	10·5	9·6	9·7	35·12	27·0	20·0	23·9	29·1
Braemar	Aberdeen	8·5	8·0	6·9	6·4	6·2	6·6	8·0	10·2	9·5	10·8	10·7	8·2	36·42	24·7	19·5	24·8	31·0
Blackstock, Midmar	,,	6·2	7·3	7·7	7·4	6·2	6·5	9·3	10·7	9·2	10·5	9·7	9·3	32·01	22·8	21·3	26·5	29·4
Aberdeen	,,	7·5	7·6	7·5	7·0	6·4	5·7	9·0	9·8	9·6	9·3	10·1	10·5	30·93	25·6	20·9	24·5	29·0
Tillydesk	,,	7·9	8·0	8·1	6·7	5·9	5·4	8·1	9·0	9·2	10·2	10·5	11·0	33·25	26·9	20·7	22·5	29·9
Gordon Castle	Banff	6·4	6·1	7·2	6·3	6·7	6·5	9·1	11·1	10·5	10·6	10·5	9·0	29·52	21·5	20·2	26·7	31·6
Highfield, Elgin	Elgin	7·3	6·2	7·1	6·0	7·2	7·4	10.5	10·7	9·9	10·0	9·2	8·5	27·17	22·0	20·3	28·6	29·1
Nairn	Nairn	8·2	6·2	6·9	5·2	6·7	7·0	10·7	11·3	10·6	9·8	9·4	8·0	24·27	22·4	18·8	29·0	29·8
IRELAND.																		
Blackrock, Cork	Cork	12·1	10·1	7·6	6·6	5·9	6·6	6·4	7·8	8·2	8·8	9·9	10·0	42·14	32·2	20·1	20·8	26·9
Parsonstown	King's County	9·5	6·7	7·1	6·2	6·8	7·3	9·0	10·3	9·6	9·6	8·6	9·3	32·86	25·5	20·1	26·6	27·8
Woodstock, Inistioge	Kilkenny	11·8	8·7	7·1	6·9	6·3	5·8	7·3	8·6	8·5	10·0	8·8	10·2	43·31	30·7	20·3	21·7	27·3
Browne's Hill, Carlow	Carlow	10·0	8·3	7·0	7·0	6·7	6·4	7·9	9·3	9·2	9·8	8·5	9·9	34·54	28·2	20·7	23·6	27·5
Red Hill, Belturbet	Cavan	10·0	7·2	7·2	6·5	6·6	7·3	9·6	9·1	9·0	9·3	9·0	9·2	35·63	26·4	20·3	26·0	27·3
Florence Court	Fermanagh	12·0	8·4	6·8	5·4	5·5	5·5	7·0	8·6	8·6	10·3	11·3	10·6	48·27	31·0	17·7	21·1	30·2
Edenfel, Omagh	Tyrone	9·6	6·8	6·5	5·7	6·3	7·1	9·1	9·7	9·8	10·0	9·8	9·6	36·82	26·0	18·5	25·9	29·6
Armagh	Armagh	9·2	7·3	6·7	6·8	6·5	6·8	10·2	9·2	9·7	9·5	9·2	8·9	31·45	25·4	20·0	26·2	28·4
Waringstown	Down	9·5	7·2	6·8	6·5	6·7	6·7	10·2	9·6	9·5	9·0	9·2	9·1	33·25	25·8	20·0	26·5	27·7
Belfast	Antrim	9·2	7·7	6·8	5·9	6·8	6·1	8·9	9·5	9·7	10·6	9·9	8·9	33·68	25·8	19·5	24·5	30·2
Moneydig, Garvagh	Londonderry	10·2	7·5	6·8	5·8	6·0	6·3	8·5	9·4	9·3	10·0	10·7	9·5	39·77	27·2	18·6	24·2	30·0
Bellarena, Limavady	,,	8·9	7·2	7·1	5·8	5·9	6·5	9·1	9·7	9·3	10·0	11·1	9·4	38·24	25·5	18·8	25·3	30·4

DISCUSSION.

The PRESIDENT (Dr. C. THEODORE WILLIAMS) said that great praise was due to Mr. Mellish for his admirable and interesting communication, involving, as it did, so much labour and research.

Mr. F. GASTER said that as a period of 35 years had elapsed since the investigations of rainfall mentioned in the paper occurred, he was afraid that he had forgotten the details of some of his earlier work. At that time there were only a few stations available, and those records were for a much shorter period than could be desired. Now there were vastly more figures at command; but Mr. Mellish, however, was right in saying that still there was too little information to discuss in much detail. He was pleased that Mr. Mellish had taken the matter in hand. He himself had only been prevented from doing so by ill health, which had prevented him even from attending the Meetings of the Society during the last two years. The question was, why should it be that the changes in distribution of rainfall to which attention had been drawn should occur? We know that in a general way the rain in mountainous districts will be greatly in excess to that experienced in more level parts; and we find also that in different seasons of the year proportion of the fall varies considerably. In summer the incoming currents are from over a comparatively cold sea, and flow over districts comparatively warm; while in autumn, the breezes from the Atlantic are from a warm sea, and are spreading over land which is becoming colder. We should thus expect, as a rule, more rain in autumn than in spring. Local peculiarities presented many other difficulties, but he thought they were outside the scope of the present paper, and were often due to local irregularities on the part of the observer. Perhaps some such cause might account for the deficiency of rainfall at Bosley Minns. In the wet districts, which were mostly mountainous, it was hardly to be wondered at that the winter rainfall was greatest. In the drier quarters the summer maximum was in his opinion largely due to thunderstorm disturbances, which, although very rare in the winter, were of frequent occurrence in the summer, especially after a hot dry period. Thus a hot dry month would be closed by one or two days of heavy rain, and the average for the month was made up. These thunderstorms were often of great severity, and their occurrence accounted for a maximum percentage of rainfall occurring in these parts in the summer months. In winter a series of depressions were continually rolling in from the west and south-west, and as the South and South-west winds of these mountains struck the mountains in the west and north-west they were robbed of their moisture. Maury aptly compared such mountains to a hand, the atmosphere being likened to a sponge, which deposited its accumulations of moisture in those districts—the more powerful the hand the greater the squeezing power. Thus by the time the depressions reach the eastern districts they have been freed of most of their moisture, and so there was a winter maximum in those hills. The effect of thunderstorms in the western and north-western districts is small, and they often occur in winter also. With regard to the continental influence spoken of by Mr. Mellish, he had not made much investigation of it himself, but he was certain that it was felt on the east and south-east coasts very much. The rainfall of the west of France was somewhat similar to that experienced on our own western shores, as was to be expected, for the effect of the Atlantic winds would be felt a good deal there. He was greatly indebted to Mr Mellish, and would be glad to avail himself of several of his conclusions in future investigations. He regretted that errors had been found in the tables. They had been checked by three different persons, and every effort had been made to secure their accuracy.

Mr. SOWERBY WALLIS said he felt much indebted to Mr. Mellish for what he considered an exhaustive discussion of the subject, although the author did not call it so. Very few persons could appreciate the enormous amount of work entailed in discussing so vast a mass of figures. The method of dealing with the values expressed as percentages was an admirable one for exhibiting the facts, but he thought it necessitated the application of a correction for the different lengths of the months. With respect to the Bosley Minns gauge, although he had not seen it he was sure its indications were misleading. It was one of the gauges belonging to the Great Central Railway, and was fixed 3 ft. 6 ins. above the ground. From its height above sea-level it was no doubt in a very exposed position, and a large proportion of the rain in winter was blown over it, and the fact that it compares more favourably in the summer than in the winter was probably due to the calmer conditions prevailing then, which allowed the gauge to receive more nearly its proper quantity of rain. In the two diagrams exhibited, drawn from Bartholomew's Atlas, of the driest and wettest months, he thought the values would be greatly modified if a longer period than 25 years had been available. Recently, in dealing with a record of drought in Devonshire, he had found 30 years insufficient, and had been obliged to supplement the figures with an 80 years' record at Exeter. On the diagram of monthly rainfall at Seathwaite he would much like to see the curve for the 50 years published in *British Rainfall*, 1895, added for comparison with the curve for the 25 years dealt with in the paper.

Mr. JOHN HOPKINSON said that he had lately been devoting much attention to the subject of rainfall. He had not confined his work to any one publication, but had obtained records of the monthly rainfall from 288 stations in England alone for the 10 years 1881-90. These records gave a mean annual fall of 31·58 ins.—14·87 ins., or 47 per cent, for the summer 6 months; and 16·71 ins., or 53 per cent, for the winter 6 months. The seasonal percentages were: winter 24 per cent, spring 21 per cent, summer 25 per cent, and autumn 30 per cent. Thus autumn is wettest and spring driest, while summer is wetter than winter. He had divided England into four districts—the northern, midland, south-eastern, and south-western counties—and he found that in each one autumn is the wettest season and spring the driest; but that while in the northern, midland, and south-eastern counties summer is wetter than winter, in the south-western the reverse is the case. In dealing with the rainfall of Hertfordshire alone, and working on 60 years' averages (1840-99), he had found the same rule hold good, the seasonal percentages being winter 22·6 per cent, spring 20·6 per cent, summer 26·7 per cent, and autumn 30·1 per cent. September was generally supposed to be the wettest month in the year, but of late years October and November had been wetter than September. In the 10 years' *Rainfall Tables* (1881-90), published by the Meteorological Office, he had only found about half a dozen errors, which he thought were very few considering the quantity of printed figures.

Mr. H. S. EATON agreed generally with the author's deductions and Mr. Gaster's remarks. The Dorset rainfall observations taken since 1848, which he had discussed at length,[1] proved that a period of 25 years was hardly long enough to give definite results of the monthly distribution of the rain. He had calculated year by year the proportionate monthly fall since 1856, every month being corrected for the unequal number of days in the month. In the 20-year period 1856-75 October was the wettest month, May the driest; November was less rainy than September, October, December, and

[1] *Proceedings Dorset Natural History and Antiquarian Field Club*, vols. xvi. to xxi., *passim*.

January. In the next 20 years (1876-95) May maintained its position as the driest month, while November was the wettest, October occupying the second place. Since then July, on the average, had been much the driest month, December the wettest.

Mr. F. C. BAYARD inquired as to the height of the stations above sea-level and as to their position. Mr. Eaton had discussed the question of the increase of rainfall with elevation, and he showed that up to 1500 feet there was an increase, but after that altitude the amount fell off. In the present paper there is nothing to show the heights of the gauges above sea-level or their position east or west of rising ground, which he thought would probably account for many of the peculiarities evidenced in the tables.

Mr. H. S. EATON explained, in reference to Mr. Bayard's remarks, that where the height of the hills above sea-level was moderate, although as a rule the rain increased with the elevation, the amount depended more on the aspect in regard to the prevalent rainy wind, which, in Dorset, was from between South-west and West-south-west, the rain being more copious on the lee side of a hill than on the south-western or exposed side. At Shaftesbury, the highest rainfall station in the county, the altitude exceeding 720 feet, under a well-exposed western aspect, the annual rainfall was 32½ ins., being nearly 2 ins. less than the average of the whole county: farther on to the east, beyond the crest of the range of hills on which Shaftesbury is situated, the rainfall was considerably larger.

Mr. HOPKINSON remarked that farmers in constructing dew-ponds usually selected a position just over the crest of a hill on its northern or north-eastern slope, as experience showed that on the Downs in the south of England, where alone dew-ponds abound, most of our rain as it came from the south-west was deposited on the leeward side of the highest ground.

Dr. H. R. MILL said that he considered the selection of the stations to be discussed was of great importance in all rainfall work. It was important that they should be chosen so as to represent proportionally the different rainfall divisions of the district in question, though he confessed that it would be very difficult to do this. He cordially supported the observation of Mr. Gaster's that, valuable as the collection and discussion of facts were, the thing to aim at was the explanation of the facts. As a basis for discussion likely to bring out the reasons for existing distributions, he welcomed Mr. Mellish's work.

Dr. J. D. PARKER remarked that he had frequently noticed, especially during thunderstorms, that heavy rain would fall in the valley all round him, but very little at his own station on the top of the hill. Perhaps a similar reason would account for the deficiency at Bosley Minns. It was very much to the point to know the exact position of the gauge.

Mr. F. GASTER thought that Mr. Mellish had already distinguished between the heights and positions of the stations; he had carefully compared the high north-western with the low eastern stations. He was unable to understand how any one could say that after 25 years' observations nothing could be got out of them. In considering local variations in rainfall, 25 or 30 years was probably not long enough, but Mr. Mellish had taken figures from all over the country. If we wait for another 30 years it is probable that none amongst us present would be there to discuss the figures, but the world would rightly blame us for not using what we have. The question was how are we going to get at the information required? We must take the different types of weather, such as that associated with South-west winds, and compare them with periods of North-east winds, instead of holding hard and fast to the arbitrarily chosen calendar months, and we should get much better results. For instance, during the past few weeks extraordinary weather had been experienced, extending over parts of two months; but if a colder, more seasonable period set in, the means for December,

taken in the usual way, would lose all distinctive features. He hoped the time would come when the consideration of the different types of weather would claim the attention it deserved, and we should then arrive at better conclusions.

Capt. A. CARPENTER remarked that he thought the regularity of the lines of percentages in the diagrams had not been sufficiently considered by several of the speakers, for that general regularity seemed to dispose of the idea that the results could to any appreciable degree be vitiated by the local lie of the instruments.

Mr. H. MELLISH, in reply, said that he could not help thinking that for a discussion of the causes of the distribution of rainfall it would be better to deal with individual months or shorter periods rather than with averages of a number of years. There was a difficulty in using a greater number of years, as the longer the period, the fewer the stations available. The heights above sea-level of the various stations could be easily given, and their general position could be readily found by referring to the map of the county, but a statement of the local aspect of the individual stations would require a very detailed topographical knowledge.

Mr. R. C. MOSSMAN, in a note to the Secretary, said:—"One of the most striking features of the month to month differences was the great excess of the July rainfall over that of June along the eastern watershed of the British Isles. This excess appeared to reach a maximum in the neighbourhood of Leith, where the 25 years' averages discussed by Mr. Mellish show a mean percentage for June 7·6 per cent, and for July 12·1 per cent; but on taking the Edinburgh means for 120 years the respective values were 8·4 per cent and 10·9 per cent. The excess of the July rainfall over that of June on the long average was only 2·5 per cent, but for the short period under review 4·5 per cent—a result brought about by the unusual dryness of the Junes and the comparative wetness of the Julies during the period 1866-1890. This anomaly appeared to be confined to the eastern parts of the country, as exactly the opposite state of affairs prevailed in the western districts.

A Remarkable Sunset.—On November 18, 1897, the morning was extremely dull and dark. Leaving home (4 miles from Ross) about 2 p.m., I noticed that the sky was clearing in the north-west, and on reaching Hereford the sun was coming out. An engagement there at 4 p.m. detained me until 4.45, when I went to the Wye bridge, reaching there about 4.50. The bridge runs very nearly north and south, and on the western side is a reach of the river coming down almost straight for a distance of 1½ miles. From the west-south-west the sun was apparently just reaching the ridge of the Black Mountains, which at that part are about 1800 ft. in height and about 15 miles distant. The sun was perfectly clear, and I never remember to have seen a sunset so clear and free from cloud or mist. The effect of the light reflected from the sky straight down on the near prospect was extremely beautiful. The river shone like a band of molten silver, and every object in front was brought out in a way rarely seen. But the most singular fact was that the apparent sunset was retarded for not less than 40 minutes. The almanac sunset time for November 18 is 4.5 p.m. The longitude is 2° 43′ W., and the latitude is 52° 3′ N. or 34′ north of Greenwich. And the horizon is a little higher than the true horizon. The sun did not set before 4.57 p.m., say 40 minutes after time. This was doubtless due to refraction, but what occasioned the refraction?—JOHN T. SOUTHALL.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

November 21, 1900.

Ordinary Meeting.

Dr. C. Theodore Williams, President, in the Chair.

Frederick March, Westgate, Falkland Road, Torquay;
Miss Filia Eleanor Anne Parker Parker, Bennington House, Stevenage;
Arthur H. Waller, Borough Engineer's Office, Durban;
B. Robert Williams, Lekondi, Gold Coast, West Africa; and
Charles Alfred Woolnough, 42 Queen's Gate Gardens, S.W.,
were balloted for and duly elected Fellows of the Society.

The following communications were read:—

"An Improved Mounting for the Lens and Bowl of the Campbell-Stokes Sunshine Recorder." By Richard H. Curtis, F.R.Met.Soc. (p. 63).

"Weekly Death-Rate and Temperature Curves, 1890-1899." By W. H. Dines, B.A., F.R.Met.Soc. (p. 69).

December 19, 1900.

Ordinary Meeting.

Dr. C. Theodore Williams, President, in the Chair.

Sir Charles Thomas Dyke Acland, Bart., Killerton, Exeter;
Andrew Walker Bell, Assoc.M.Inst.C.E., Dunfermline;
Capt. Joseph Grant Bickford, H.M.S. *Mount Edgcumbe*, Saltash;
Septimus Brocklehurst, Sefton Park, Liverpool;
Lieut. Maurice Harvey Clarke, R.N.R., Coleswood, Harpenden;
Robert Downs, 186 Denmark Hill, S.E.;
James Carlton Eckersley, M.A., Carlton Manor, Yeadon, Leeds;
Evan Oswald Evans, 80 Main Street, Cadoxton, Barry Dock;
Capt. Arthur Mostyn Field, R.N., H.M.S. *Research*, Portsmouth;
Henry Dent Gardner, Fairmead, The Goffs, Eastbourne;
John Kitching, Oaklands, Kingston Hill, S.W.;
Ole Theodor Olsen, 116 St. Andrew's Terrace, Grimsby;
Kôzui Ôtani, 33 Warwick Square, S.W.;
Erasmus John Burgess Sopp, Hoylake, Cheshire;
John Robert Tustin, Albion House, The Marina, Deal;
Col. Francis Richard Waldo-Sibthorp, 41 Sillwood Road, Brighton; and
Carlen Lacey Weller, The Plantation, Amersham,
were balloted for and duly elected Fellows of the Society.

Mr. F. Gaster and Mr. M. Jackson were appointed Auditors of the Society's Accounts.

The following communication was read:—

"The Seasonal Rainfall of the British Isles." By Henry Mellish, F.R.Met.Soc. (p. 79).

CORRESPONDENCE AND NOTES.

Low Humidity and High Temperature.—A correspondent in Jamaica recently wrote stating that he wanted "to find out what was the relative humidity of the atmosphere in London at any periods during this year—or before—when the temperature was (1) between 80° and 85°, (2) between 85° and 90°, and (3) above 90°. You will understand that it is the humidity at the actual time of the high temperature, not at 9 a.m. or 9 p.m. of the days when the high temperatures occurred, that I wish to know.

"The statement appeared in the *Gleaner* that the heat in Jamaica was much more bearable than that in England, because the air was so much drier here.

"The average humidity for all temperatures and all times of the year is probably greater in England, but when our temperatures are in the nineties our humidity is never less than about 60 per cent, whereas in England at the same temperature I believe it to be far lower. Our temperature, of course, never goes below 56°."

As it was thought that the Greenwich records would best furnish the data required for answering this inquiry the Astronomer Royal was communicated with, and he has supplied the accompanying statement showing the temperature and humidity of the air at Greenwich on hot days in 1900. As the maximum temperature and the lowest humidity may not in all cases occur at the same time, the simultaneous eye-readings of the dry and wet bulb thermometers with the deduced relative humidity at noon and at 3 p.m. are also given.

Temperature and Humidity at the Royal Observatory, Greenwich, on hot days in 1900.

	Max. Tem. in Shade.			Noon.			3 p.m.		
1900.	Dry bulb.	Wet bulb.	Relative Humidity.	Dry bulb.	Wet bulb.	Relative Humidity.	Dry bulb.	Wet bulb.	Relative Humidity.
	°	°	%	°	°	%	°	°	%
June 10	81·2	64·5	38	78·5	62·0	38	...	...	...
" 11	89·4	73·5	41	86·8	70·9	41	86·9	67·7	34
" 12	82·6	71·0	52	75·1	67·7	64	81·7	69·8	50
July 10	82·7	67·1	41	76·5	59·7	36	81·3	65·3	39
" 11	84·7	69·3	42	83·0	68·7	44	82·0	65·1	38
" 13	83·6	69·9	46	78·8	67·1	51	79·5	67·7	51
" 15	84·1	69·7	44	74·4	63·7	53	...	...	...
" 16	94·0	75·7	38	91·4	73·9	39	83·0	71·7	53
" 17	82·9	65·1	36	76·7	63·7	47	80·5	64·4	39
" 18	85·3	70·0	42	79·6	64·7	42	83·7	68·4	42
" 19	91·7	72·3	35	86·7	68·4	35	90·1	71·6	37
" 20	90·2	75·9	46	88·6	74·9	47	88·5	73·8	44
" 22	80·9	67·1	46	76·3	65·4	52	...	...	...
" 23	82·9	69·8	48	74·9	65·9	58	80·4	67·5	47
" 24	88·2	74·1	46	83·6	69·9	46	87·4	71·7	42
" 25	93·0	72·1	32	89·7	70·6	35	91·6	71·0	33
" 26	80·7	66·1	43	76·6	64·6	49	76·7	63·9	47
Aug. 13	82·1	69·1	48	78·7	67·2	51	80·3	64·8	40
" 14	81·4	66·0	40	78·0	64·0	44	80·7	64·7	39
" 17	81·9	70·8	53	76·7	68·0	61	80·9	69·3	51
" 18	81·7	71·1	54	78·7	68·7	56	81·3	70·7	54
Sept. 16	82·6	68·9	46	76·0	67·2	60	...	...	...

On Sundays the 3 p.m. observation is not taken.

[The degree of humidity has been calculated by means of Glaisher's *Hygrometrical Tables.*]

Thunderstorm Observations during a Balloon Ascent.—The following is a translation of a note by Dr. R. Börnstein published in the *Meteorologische Zeitschrift* for August 1900 :—

On June 8, 1900, the balloon *Condor*, with three lieutenants of the Prussian balloon corps, got into the vicinity of a thunderstorm during an ascent from Berlin. The balloon was moving from south-west at about 11.30

a.m., at the height of 2300 ft., just over Kaulsdorf (about 5 miles east of Berlin), and was enveloped in cloud, but occasionally the earth was visible through chinks in the cloud. The chief balloonist, Lieut. de le Roi, heard a sharp crackling sound at the ring of the car, like the noise of sparks from a large electrical machine, and, when he looked up, he saw a spark 27 ins. long, and about 0·5 in. in section, move up at an angle of 120° to the car ring. Lieut. Priu reported that while a flash was passing he saw the ring illuminated, and at the same time heard loud crackling. Lieut. Davids noticed "an electrical spark, like a lightning flash, pass between balloon and car, with a loud hissing sound." Thunder was heard before and after this phenomenon, and the supposition is that at that moment the thunderstorm was above the balloon. They had to descend as quickly as possible, and it was found that the available ballast, which under ordinary circumstances would have checked the rate of descent, was quite insufficient for the purpose. Although sand was constantly being thrown out, the balloon struck the ground with a great bump.

Here it should be remarked that the car ring above mentioned was of metal, and attached to the cords hanging from the net, while the car was suspended by ropes from the ring. The upper end of the tow-rope was made fast to the ring. This had a strand of wire in it, and was 330 ft. long; and so, as it hung, it established a connection between the car and the stratum, 330 ft. below. There can be no doubt that at times of thunderstorms very great electrical differences must exist, but nevertheless the single bright spark which the balloonists observed must be held to be an action of induction from a flash passing close by, inasmuch as the thunder heard before and after proves that there was certainly a thunderstorm close by.

It is certainly remarkable that no thunderstorm broke over Berlin that afternoon. I therefore went to the Royal Meteorological Institute, where the authorities, with the utmost readiness, placed all their reports of thunderstorms on the morning of June 8 at my service. These showed me that neither at Berlin itself, nor anywhere in the neighbourhood to the east-north-east or south-east, was any thunderstorm reported. The nearest stations from which any such reports came in were Blankenburg and Eberswalde to the north, Reppen and Landsberg on the Warthe to the east, Sperenberg and Zinna to the south. On the whole, there were 26 stations reporting thunderstorms, mostly to the southward and westward; and if the reports are plotted on a map you can clearly trace two groups of stations, separated by a broad belt, along which the Oder flows. There are at least 10 or 12 stations in this belt which reported no storms. The belt is traversed by several streams running into the Oder, and it is surrounded by 8 stations on the left, and 18 on the right bank, which did report storms. The times of the storm on the left bank of the Oder were from 10.30 to 11.1 a.m., those on the right bank were mostly between noon and 1 p.m.

Along the belt between these two groups no actual thunderstorms were observed, but the concomitant phenomena were clearly perceptible. The apparatus at the Agricultural Training School at Berlin showed an increase of pressure (storm-hump) of 0·15 in. between 10.47 and 10.57 a.m., a drop of 6°·6 F. at 10.42, a freshening of wind at 10.57, a temporary breeze from West-north-west between 10.42 and 11.7, while the wind had been West-south-west both before and after. There was also a sharp shower of 0.12 in. between 10.52 and 11.7, so that all the characteristic marks of a squall, such as usually occurs near a thunderstorm, were noticed.

And all this time the balloon was floating over this belt where no storm broke, while the observations recorded in the car, at the height of over 2000 ft., showed clearly that a thunderstorm was going on above. If we assume that the squall and the storm were in an ascending current while they were passing

the balloon, we can easily see how the descending current which ensued pressed the balloon down, and brought it to the ground with a bump.

From the station reports above quoted we can see that the storm came up from West-south-west towards the left bank of the Oder, and then was checked in its advance by the Oderbruch, the very wet and partially marshy plain of the Oder, and was unable to develop itself until it had got to a good distance from the right bank.

Such an interference with the motion of thunderstorms caused by water has often been noticed before, and I myself have cited several instances of it in a former paper.[1] The river in the warmer seasons is cooler than the air, and so generates a descending current, which neutralises the ascending current of the thunderstorm squall. "If, however, the squall extends to a level higher than that of the ascending current, the upper part of the storm can cross the river and move onwards." This idea, which I broached formerly, seems to be confirmed by the observations of June 8. While the storm appeared from the observations at the stations at ground level to be stopped by the Oder, the men in the balloon observed that the storm sprang over the river and was developed at the upper levels.

Dynamical Meteorology.—Dr. H. H. Hildebrandsson and Mons. L. Teisserenc de Bort have for some time been engaged upon a work entitled *Les Bases de la Météorologie Dynamique.*

This book was commenced in 1898, and as yet only three parts, not consecutive, have appeared. In addition to the words quoted above, the title-page bears the words "*Historique—État de nos connaissances.*"

It commences in Chapter I. with the oldest researches on Trade winds and general circulation of the atmosphere, coupling with them the names of Halley, Hadley, Dove, and Maury, and giving a summary of the work of each.

This is succeeded by Chapter II., in which we learn of the first announcements of the Law of Storms. Apparently the first to propose that ships might be manœuvred, so as to escape West-Indian hurricanes, was Capt. Langford in the *Phil. Trans.* for 1698. The next great step in advance was by Redfield in 1831. In 1847 Reid actually organised a system of storm-warnings from Bridge Town to Carlisle Bay in Barbadoes.

In Chapter III. we have the centripetal theories of Brandes, Espy, and Loomis.

In Chapter IV. we trace the gradual development of the present weather services, and among the earliest proposals made by the founders of our science are given those of F. B. Martin (1852), *A Memoir on the Equinoctial Storms of* 1850; W. H. B. Webster (1857), *Recurring Atmospheric Periods;* and F. Galton (1863), *Meteorographica*, a work which our authors designate as "one of the most important in the domain of dynamic meteorology." The chapter concludes with a summary of the various proceedings of Le Verrier, FitzRoy, and Buys Ballot, and brings us down to the year 1864.

Chapter V., "Fundamental Researches in Different Countries, 1865-72." The first part of this chapter is devoted to a discussion of Dr. Buchan's two early memoirs: "Examination of the Storms of Wind in Europe, Oct.-Dec. 1863," and "On Two Storms which passed over the U. S., March 13-22, 1859." This is followed by a notice of Jelinek's work (1867), and then that of Mohn in Norway and of the Swedish establishments. Mohn's *Storm Atlas* (1870) is discussed at considerable length, and subsequently Dr. Hildebrandsson's (*Stormarna den* 13-21 *Oktober* 1869). Then follows an account of the reorganisation of the English Meteorological Department in 1867, and of Clement Ley's

[1] Börnstein, "Die Gewitter vom 13 bis 17 Juli 1884 in Deutschland." *Aus dem Archiv der D. Seewarte*, viii. No. 4, 1885. Abstract, *Met. Zeitsch.* iv. 1887.

Laws of the Winds in Western Europe. The chapter winds up with a notice of various *Atlases* of weather charts by Le Verrier, Hoffmeyer, and others; and at the very end gives very carelessly the name of Dr. Buchan, instead of that of Dr. Carl Bruhns, as the third signature with Jelinek and Wild, to the invitation to the Leipsic Conference, 1872, at which international co-operation in meteorology was first set on foot.

Chapter VI. deals with aqueous vapour, and it points out that the first crucial experiment to show that vapour rose from water and was condensed by cold, was due to the Rev. J. T. Desaguliers (*Phil. Trans.* 1729), and that Dalton was the first to lay down the laws of vapour. It then proceeds to cite the several physicists, such as von Lamont, Kämtz, Bessel, Strachey, Hann, and Hildebrandsson, who have successively handled the subject of the distribution of vapour.

The cause of rain is the next subject met with, and here it is Peslin in the *Atlas Météorologique de l'Observatoire de Paris*, in his paper "Sur les Mouvements généraux de l'Atmosphére," who first applied the formulæ of thermodynamics to atmospheric phenomena, including the behaviour of vapour. The idea of Dalton, attributing rain to the mixture of different masses of air, was finally disproved by von Bezold and others, and the chapter winds up with a mention of Aitken's nuclear condensation. Melander, in Finland, has also worked on the same lines.

With this chapter we have a break, as Part III. is not yet out. Part IV. begins Vol. II., and its first chapter is taken up with the distribution of meteorological elements around barometrical maxima and minima. This is dealt with in considerable detail (144 pp.), and contains in Section 1 numerous tabular extracts showing the distribution of wind inclination to isobars in the different azimuths. Section 2 treats of the altitudes affected by cyclonic disturbances, as revealed by *cirrus* observations. Section 3 is devoted to the velocity of the wind, the gradients, and the central calm. Section 4 treats of the temperature of the air. It is by far the fullest, as it treats the subjects from so many different points of view, especially from that of the inversion of temperature with elevation under certain circumstances, and from that of the relation of temperature to barometrical maxima and minima.

Section 5 is devoted to the distribution of cloud, rain, and fog.

The whole work has not been carefully read in proof. Many letters have been printed wrong, especially in English quotations, but also in German and French. We have above given an instance of serious neglect in attributing credit to a wrong person.

Greenwich Observatory.—Mr. E. W. Maunder has just published a very interesting book entitled *The Royal Observatory, Greenwich: A Glance at its History and Work*, which is illustrated with portraits of the various Astronomers Royal and photographs of many of the instruments and buildings of the Observatory. The lives of the Astronomers Royal form practically the history of the Observatory; so Mr. Maunder has given a brief biography of each, showing the advance made in the work of the Observatory during his regime. There have been eight Astronomers Royal:—

Rev. John Flamsteed	1675–1719
Edmund Halley	1720–1742
Rev. James Bradley	1742–1762
Rev. Nathaniel Bliss	1762–1764
Rev. Nevil Maskelyne	1764–1811
John Pond	1811–1835
Sir George Biddell Airy	1835–1881
William Henry Mahoney Christie, C.B.	1881 to present time.

The work of the Observatory is perhaps best described in the words of Airy:—

"The Observatory was expressly built for the aid of astronomy and navigation, for promoting methods of determining longitude at sea, and (as the circumstances that led to its foundation show) more especially for determination of the moon's motions. All these imply, as their first step, the formation of accurate catalogues of stars, and the determination of the fundamental elements of the solar system. These objects have been steadily pursued from the foundation of the Observatory: in one way by Flamsteed; in another by Halley, and by Bradley in the earlier part of his career; in a third form by Bradley in his latter years; by Maskelyne (who contributed most powerfully both to lunar and to chronometric nautical astronomy), and for a time by Pond; then with improved instruments by Pond, and by myself for some years; and subsequently, with the instruments now in use. It has been invariably my own intention to maintain the principles of the long-established system in perfect integrity; varying the instruments, the modes of employing them, and the modes of utilising the observations of calculation and publication, as the progress of science might seem to require."

The scope of the work has increased since that time, the various Departments treated by Mr. Maunder being (1) Time; (2) Transit and Circle; (3) Altazimuth; (4) Magnetic and Meteorological; (5) Heliographic; (6) Spectroscopic; (7) Astrographic; and (8) Double Stars.

In 1836 Airy proposed to the Board of Visitors the creation of the Magnetic and Meteorological Department, and in 1840 a system of regular two-hourly observations was set on foot, which was a few years later superseded by photographic registration.

The two following extracts show the difficulties of making certain observations, and also illustrate the pleasant style of writing adopted by Mr. Maunder:—

"An amusing difficulty was encountered in an attempt to set on foot another inquiry. The Superintendent of the Meteorological Department at the time wished to have a measure of the rate at which evaporation took place, and therefore exposed carefully measured quantities of water in the open air in a shallow vessel. For a few days the record seemed quite satisfactory. Then the evaporation showed a sudden increase, and developed in the most erratic and inexplicable manner, until it was found that some sparrows had come to the conclusion that the saucerful of water was a kindly provision for their morning 'tub,' and had made use of it accordingly."

"Besides the movements of the magnetic needle, the intensity of the currents of electricity which are always passing through the crust of the earth are also determined at Greenwich; but this work has been rendered practically useless for the last few years by the construction of the electric railway from Stockwell to the City. Since it was opened, the photographic register of earth currents has shown a broad blurring from the moment of the starting of the first train in the morning to the stopping of the last train at night. As an indication of the delicacy of modern instruments, it may be mentioned that distinct indications of the current from this railway have been detected as far off as North Walsham, in Norfolk, a distance of more than a hundred miles. A further illustration of the delicacy of the magnetic needles was afforded shortly after the opening of the railway referred to. On one occasion the then Superintendent of the Magnetic Department visited the Generating Station at Stockwell, and on his return it was noticed, day after day, that the traces from the magnets showed a curious deflection from 9 a.m. to 3 p.m., the hours of his attendance. This gave rise to some speculation, as it did not seem possible that the gentleman could himself have become magnetised. Eventually, the happy accident of a fine day solved the mystery. That morning the Superin-

tendent left his umbrella at home and the magnets were undisturbed. The secret was out. The umbrella had become a permanent magnet, and its presence in the lobby of the magnetic house had been sufficient to influence the needles."

RECENT PUBLICATIONS.

Atlas Climatologique de l'Empire de Russie. Publié par l'OBSERVATOIRE PHYSIQUE CENTRAL NICOLES à l'occasion du Cinquantième Anniversaire de sa Fondation. 1849—99. St. Petersburg 1900.

This magnificent Atlas has just appeared. It contains 89 maps and 15 graphical tables, *i.e.* curves representing the march of different elements. Many of the subjects have already been represented in the several Atlases published by Prof. Wild, as, for instance, Pressure, Temperature, and Rain. All these charts have been corrected to date, and in addition there are new charts, viz. 2 charts for seasons of maximum and minimum precipitation; 2 charts for seasons of maximum and minimum days of precipitation; 2 charts for seasons of maximum and minimum amount of cloud; 1 chart for the number of days of snow lying on the ground; 1 chart for the number of days of thunderstorms; 4 seasonal charts of number of days of precipitation; and 12 monthly charts of humidity. There are only few of the elements for which the records cover the full half-century. For the most the period of observation commences with 1871, soon after the arrival of Dr. Wild to take charge of the Central Physical Observatory (1868). The maps of duration of snow on the ground only go back to 1890, those of thunderstorms to 1886, and those of degree of insolation cover the period from 1892-95, being the observations made with Chwolson's actinometer.

The Atlas is accompanied by a *notice explicative* of 61 pages in royal 8vo.

By Land and Sky. By the Rev. JOHN M. BACON, M.A., F.R.A.S. 1900. 8vo. 275 pp.

The author in this volume describes a number of balloon ascents which he has made for scientific purposes. He expresses the hope that this may serve to stimulate an interest among individuals and the public generally in a fascinating and all-important scientific pursuit.

Mémoires Originaux sur la Circulation Générale de l'Atmosphère. Annotés et Commentés par MARCEL BRILLOUIN. 8vo. 165 pp. Paris, 1900.

This is a collection of original papers on the general circulation of the atmosphere by the following writers: Halley, Hadley, Maury, Ferrel, W. Siemens, Möller, Oberbeck, and von Helmholtz.

Versuch über die Hygrometrie. Von HORACE BÉNÉDICTE DE SAUSSURE. Herausgegeben von A. J. VON OETTINGEN. 8vo. 168 pp. Leipsic, 1900.

This work forms No. 115 of Ostwald's *Klassiker der exacten Wissenschaften.* It is really a translation of Saussure's *Essays on Hygrometry,* published in Neuchatel in 1783, in which he describes (1) his Hair Hygrometer, and (2) the Theory of Hygrometry.

Stanford's Geog! Estab! London

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THE CLIMATE OF NORWAY AND ITS FACTORS.

BY C. THEODORE WILLIAMS, M.A., M.D., F.R.C.P., PRESIDENT.

An Address delivered to the Royal Meteorological Society, January 16, 1901.

(Plate I.)

NORWAY, the land of the Viking and of the Saga, the land of the fjord and of the fjeld, with its snow-capped cliff mountains, its superb waterfalls, its huge glaciers, and deep fjords, reaching far into the heart of the country, has always appealed strongly to Englishmen on the grounds of the beauty of its scenery, of the field it offers for sport in the way of fishing and shooting, and on account of the kinship of our race with its manly and vigorous people.

Its meteorology should prove an attractive study for this Society, as having much in common with that of our country, both the Norwegian and the British shores being influenced by the same warm Atlantic current, and having their winters and summers tempered by the same equalising agency.

Before discussing the meteorology it will be well to say a few words on the geographical position and on the conformation of this interesting land, as both have an important bearing on the climate.

Norway lies between latitudes 57° 58′ N. and 71° 11′ N. and between longitudes 4° 30′ 5″ and 31° 12′ 5″ E. of Greenwich; that is to say, its southernmost point, Lindesnœs, is in the latitude of Dornoch in South Sutherlandshire, and its most northerly point, Knivskjœrrodden, on the island of Magero, in the latitude of Jan Mayen.

Norway is bounded on the south by the Skagerrack, on the west by the North Atlantic Ocean or Norwegian Sea, on the north by Barentz Sea, and on the east by Sweden, Lapland, and Russia.

The *first* point we need notice is its insular character, for the country has an area of 122,788 square miles, while the coast-line, including the islands, bays, and fjords, is 3018 miles, showing how largely the land is

intersected by the sea, and how deeply the Atlantic waters penetrate into the heart of the country. The islands occupy one-seventh of the entire surface of Norway, the largest, Hindöen, being 865 square miles in extent. The fjords, or sea-water lochs, running into the interior, branch in several directions, and thus some of the loftiest mountains have their bases washed by the sea: the Sogne fjord flows nearly 100 miles inland, taking for the most part an easterly direction, and laving the southern base of the Jostedalsbrœ, the largest glacier in Norway; the combination of mountain and glacier and forest with the sea forming one of the charms of the scenery. We can return to the fjords later on.

There are many evidences of rise of the coastline in Norway. Along the shore between Sönd-Hordland and Eastern Finmark ancient sea-beaches have been discovered, either on the fjord shores or on the coast itself. They indent the land, and are sometimes cut into the rock, and always at a considerable height above the present high-water mark. These are to be found at Fröien, near Christiansund; at Stenbjerget, near Trondhjem; at Bossekop in Alten Fjord; and at Vargesund, between Alten and Hammerfest.

There is also a well-marked one on the Romsdals Fjord, near Veblungsnœs, which I inspected last autumn. It was at least a mile long, about 100 feet above the fjord level at high-water, and was nearly flat and composed of sea sand, with a few boulders interspersed.

There are numerous caves in the islands, off the coast, which are situated high up in the cliffs, but which are found to contain sea-shells and other proofs of marine occupation, and these caverns were probably due to the action of the waves. The most remarkable of all these is in the island of Torghatten, through which a natural tunnel passes, 36 to 80 feet in breadth, 535 feet in length, and 64 to 200 feet in height, and the floor is 360 feet above sea-level. This is one of the "lions" to be visited on the voyage to the North Cape.

The *second* point is the distribution of the mountain ranges, which explains to a large extent the rainfall. Norway is a mountainous country, with scarcely any low-lying plains; and, according to Professor Broch, about 80 per cent of its surface is 500 feet above sea-level. The main mountain range begins near 69° N. latitude, and for the most part follows the coast-line, and gradually subsides into moderate elevations in the south near Lindesnœs. To the east the mountains slope gradually towards the Baltic Sea and Gulf of Finland, while to the west they preserve a higher level and sink slowly, partly in ledges, towards the sea, in the neighbourhood of which they maintain such an elevation that eventually the descent is very abrupt, or else they terminate in precipitous islands, thus extending out into the ocean itself.

In the province of Tromsö the ranges rise to 5475 ft.; the Sulitelma, east of the Salten Fjord, reaches 6718 ft.; then we have the Dovre Fjeld rising in Snehatten to 7566 ft., the Rondane to 6930 ft. between Osterdalen and Gudbrandsdalen, and next the picturesque group of the Jotunheim, with Galdhöppiggen, the highest mountain in Norway, 8400 ft.: the range diverging to the west and terminating in the Jostedalbrœ, which extends about 50 miles, and has as its highest point Lodalskaupen, 6790 ft.

From the Jotunheim the mountains are continued southwards under

the names of Hensedals Fjeld, Hallingsjökulen, and Hardangerbidden, and Folgefond, the Hartingen being 6063 ft., and then they gradually lose themselves in the moderate elevations of Southern Norway. The Norwegian mountains differ greatly from the Alps in their conformation, for instead of presenting the alternation of mountain and valley like a ridge and furrow roof, they appear, as Willich says, like the parapet of a castle, with the profound gorges as its embrasures. The consequence of this is that a great part of the country is a table-land of 2000 to 4000 ft. above sea-level, part of which is covered with eternal snow, and from this rise sundry peaks. Much of this table-land ends in precipices, down which the streams issuing from the snow-fields and glaciers, fall in magnificent cascades, often directly into the lakes, and sometimes into the fjords themselves, presenting one of the finest characteristics of Norwegian scenery. The result of the plateau arrangement of these elevated snow-clad regions is, that some parts of the snow-field, like the Folgefond, in the Hardanger, can be traversed by horses and sledges, and thus communication between adjacent valleys is maintained. The valleys west of the mountain range are usually short. On the east side the valleys are wider and longer, and contain streams and rivers. Such are the Gudbrandsdal, the Sundal, the Guldal, and the Osterdal, through which the principal railway of Norway runs; in fact, some of the leading routes lie east of the mountain range along the coast.

There are few countries which exhibit more marked or more numerous evidences of glacier action than Norway. Rock surfaces appear ground and striated up to 4000 or 5000 ft. above sea-level, and the striation always points along the valleys from the mountains towards the sea. Old moraines composed of gravel and triturated granite extend transversely to the direction of the striæ, and show the limits of ancient glaciers, and by their various levels indicate pauses in the retreat of the ice masses into the interior of the country. In most of the valleys these old moraines are to be seen, generally covered with grass or some cultivated crop, or else clothed with spruce and birch trees, with large rounded moss-clad boulders standing out to demonstrate their origin. The geology of Norway mountains shows for the most part primary rocks, rarely overlaid with more recent formations, the primary rocks consisting of granite, gneiss, clay-slate, limestone, and dolomite, granite being the prominent formation, and giving the rounded outline so characteristic of these ranges. In the Romsdal the gneiss predominates, and appears in magnificent pinnacles majestically towering to the height of 5000 to 6000 ft. in the Romsdal Horn and the Troldtinder, but these peaks and serrated ridges are quite the exception in Norwegian mountain scenery, and the prevailing features are lofty plateaux ending in precipitous cliffs.

The glaciers of Norway differ greatly from those of the Alps in shape and position. From the conformation of the mountains they are less hemmed in in narrow valleys with steep sides, and they spread over the plateaux of rock till they reach a precipice, down which the stream descends in a cascade, so that we can sometimes see from the steamer these shimmering green or blue masses of ice overhanging the cleft, while at times masses break off and fall as avalanches into the fjord.

An example of a glacier descending into a fjord may be seen in the Jokulfjeldbræ on the Jokul Fjord, where portions of ice break off and

float on the sea water like icebergs, and still more striking is the huge [illegible] glacier in Northern Norway, which flows direct to the Atlantic shore, where it scatters its numerous ice-blocks.

Now the next factor of the Norwegian climate is the waters of the Ocean, which from a variety of circumstances come into close connection with much of the country and thus temper extremes of climate. As Professor Mohn explains briefly, "Between Great Britain and the peninsula of Jutland the North Sea is rather shallow, and only in its most northern part is it more than 50 fathoms deep. The 100 fathom line passes to the west of the British Isles and to the north of the Shetlands towards the Norwegian Coast, reaching it at the headland of Stad. But the Northern Bank included by this line does not quite reach to the Norway Coast, for from Stad (62° N. lat.) a channel called the Norwegian, forming a depression in the sea bottom, passes southwards and eastwards off the western and southern coasts as far as the Christiania Fjord and the Cattegat." This channel, the Professor tells us, is deepest in the Skagerrak, reaching 400 fathoms; off Lister in South Norway it is 200 fathoms; and off Bommelen, its shallowest point, 120 fathoms. Then the Channel steadily deepens as it passes northwards, and off the Sogne Fjord it is 200 fathoms, and from this point again it steadily increases in depth until it debouches into the deep basin of the Norwegian Sea. The breadth of this deep channel varies from 50 to 70 miles, and outside it lie the Norwegian coast banks. Deep as it is, its greatest depth is surpassed by that of the fjords, which are as follows:—

Stavanger Fjord . .	380 fathoms.	Nord Fjord . .	340 fathoms.
Hardanger Fjord . .	355 "	Trondhjem Fjord .	300 "
Sogne Fjord . .	670 "	Vest Fjord. . .	340 "

It is found that the water flowing off the Norwegian coast is everywhere, and at all times, warm. At the bottom the temperature is always above 32°, on the surface of the banks it varies from 44° off the Romsdal coast to 37° in East Finmark. At the surface of the sea the record changes from winter to summer, varying from 36° to 63°; on the Romsdal coast, from 39° to 55°; in the Vest Fjord, from 35° to 54°; and at the North Cape, from 36° to 47°.

The winds prevailing most throughout the year are the South-westerly, and these have the effect of heaping up the warm waters of the Atlantic on to the Norwegian coast, so that the water off the coast is actually 1 metre higher than farther out to sea.

Now in the Faroe and Shetland Channel a temperature of 32° is found at a depth of 300 fathoms, but outside Vestralen, on the Norway coast, the same temperature is found at a depth of 600 fathoms, showing the greater warmth of the water off the Norwegian coast, and it is considered that the Norwegian coast banks bar the way to the ice-cold waters of the polar sea, and prevent the warm Atlantic currents from being cooled by waters flowing below them. The result of the presence of this warm mass of water is that the Norwegian fjords are filled with warm Atlantic water of a nearly constant temperature, which is as high as, and in the north of Norway higher than, the mean annual temperature of the air, and it represents a body of heat that the severest winter can only reduce in a very slight degree.

The depths of the Skagerrak have permanently a temperature of 41° in winter.—

Hardanger Fjord	43°·5	Salten Fjord	39°·2
Sogne Fjord	47°·3	Varanger Fjord	37°·6
Trondhjem Fjord	43°·3		

Wherever at depths of 100 to 200 fathoms the temperature is above 32°, the sea-water of course never freezes. In fjords it is only where rivers enter and the cold fresh water lies above the salter and warmer waters of the deep, or on the long shallow stretches of the coasts, that freezing takes place during severe winters. For instance, the eastern arm of the Nord Fjord froze last winter, the ice being firm enough to permit skating and walking, and even driving on it, the reason being the comparative shallowness of this end of the fjord, and the large dilution of its salt water by the volume of cold water poured into it by the Loen and Olden rivers coming from glaciers, which are extensions of the great Jostedalbrœ. The presence of this warm Atlantic water on the west coast and in the fjords of Norway points clearly to the existence of an Atlantic current flowing from tropical regions, call it what you will, Gulf-stream, or Equatorial current, and it is highly probable that the higher temperature of western Norway, as also that of the south-west coast of England, and the western coasts of Ireland and Scotland, are due partly to this, and not wholly to South-west winds, as has been lately advanced, though the latter, as before said, may have the effect of banking up the waters off the coast.

Without the existence of such a current, how can the distribution of isothermal lines in the North Atlantic be explained? or the open harbours of northern Norway throughout the winter? or the facts mentioned in the subjoined extract from Nansen's *Farthest North*.[1]

"Our observations go to show that under the cold surface of the Polar basins, which stood at a temperature of − 1°·5 C., was warm water, sometimes of a temperature as high as + 1° C., and that this water is more briny than the water of the Polar basin had been assumed to be. The warmer and more strongly saline water must clearly originate from the warmer current of the Atlantic Ocean flowing in a north or north-easterly direction off Novaya Zembla, and then along the west coast of Spitzbergen, and then diving under the colder, but lighter and less briny, water of the Polar sea, and filling up the depths of the Polar basin."

Moreover, how can we account for the mean temperature of the sea surface during winter and spring in the Norwegian Sea as seen in the map (Fig. 1) taken from Professor Mohn's well-known work on the "North Ocean, its Depths, Temperature, and Circulation," which depicts the sea surface temperature during the month of March? It will be noted that the thermal lines are bent upwards to the extent of more than a degree of latitude, and that this extends to the Arctic Circle.

When we reflect that Norway lies between 57° 58′ and 71° 11 N. lat., and adjoins Lapland and Russia, and that part of it lies within the Arctic Circle, we realise what a blessing the Equatorial current is, in mitigating extreme cold, making vegetation possible, and even in places luxuriant, and removing the obstacles to trade and commerce which snow and ice present.

[1] Vol. ii. p. 634.

The *fourth* factor of the climate is the sun, which, as is well known, in these latitudes remains in the summer long above the horizon, and

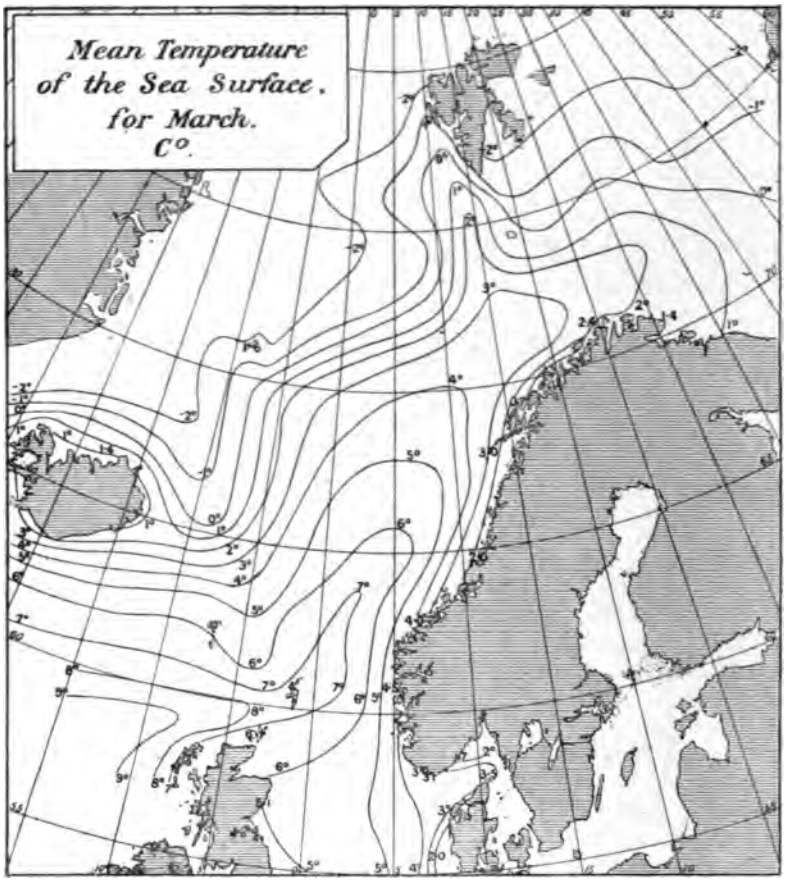

Fig. 1.

in the winter long below it. About one-third of the land is the domain of the winter sun and of the winter darkness. The sun never sets—

At Bodö, from June 1 to July 10	40 days.
,, Hammerfest, from May 14 to July 28	76 ,,
,, North Cape, from May 11 to July 30	80 ,,

On the other hand,

At Bodö the sun never rises from	December 15 to December 28	.	14 days.
,, Hammerfest ,, ,,	November 20 to January 22	.	64 ,,
,, North Cape ,, ,,	November 17 to January 24	.	69 ,,

This implies a powerful solar influence in these parts during May, June, and July, which doubtless has the effect of promoting the rapid growth of vegetation, while solar heat is exercised during the whole of the astronomical day; but we cannot withhold our pity from the unhappy dwellers in a country where the sun never appears for from 14 to 69

days of the year; and who have to be contented with twilight and the moon- and star-light, with occasional flashes of the Aurora Borealis.

It has been noticed that the leaves of most of the trees in Northern Norway are larger than those of the same kind in southern regions. Leaves of maple and plane trees transplanted from Christiania to Tromsö have been found to increase greatly in size, while the trees themselves become dwarfed in their growth, and this leaf development is attributed to the long continuance of sunlight in summer.

Barley takes the same time to ripen at Alten, 70° N. lat., as at Christiania, and it is thought that the great length of the Arctic day compensates, at all events partially, for the lack of heat.

Having now touched on the principal factors of the Norwegian climate, we come to the climate itself, which has been studied and clearly sketched out for us by the Norwegian Meteorological Institute under the able superintendence of our Honorary Member, Prof. H. Mohn.

This Institute was founded by the Government in 1866, and placed under the supervision of the University of Christiania, and at the present moment receives observations regularly from 456 stations, of which 350 are for rainfall only. The subjoined chart, taken from an excellent monograph on the climate of Norway by Herr Axel Steen, gives the chief stations and their distribution (Fig. 2, p. 112).

Temperature.—It would occupy too much time to give the full details of the meteorology, which has been exhaustively described by Prof. Mohn in his numerous and valuable contributions, so I propose merely to allude to the most salient points.

For meteorological purposes the country is divided into three parts: South-eastern Norway, bounded on the north by the Dovre mountains, which culminate in Snehatten, and on the west by the great chain running from the Romsdal to Lindesnœs, has a chiefly inland and an extreme climate.

Western Norway, including the coast region west of the chain and the numerous islands, with the great fjords which penetrate far inland, has a generally insular climate.

Northern Norway, which takes in the coast north of the Dovre Fjeld and west of Sweden and Lapland, including the Trondhjem and Alten districts with the province of Finmark and the ports of Tromsö, Hammerfest, and Vardö, is partly insular and partly inland.

The coldest districts are in the interior of Finmark, which show a mean temperature of 30° at Sydvaranger, and 26°·5 at Karasjok. The highest mean temperature is noted at Skudesnœs, near Stavanger, on the coast, and is 44°·6.

The coast-line from the entrance to the Sogne Fjord down to Lindesnœs has a mean annual temperature of 44°, the warmth increasing in winter as the coast is approached. From Lindesnœs a narrow belt can be traced along the west coast northwards as far as the entrance to the Trondhjem Fjord, where the mean temperature of the coldest day is above 32°, and this includes Nöst, the outermost of the Lofoten isles. In January the interior of Finmark has a mean temperature of 2°·5, and South-east Norway at an elevation of 1600 ft. has a temperature of 11°·3.

It will be seen that in winter the temperature rises as the coast is approached; is lowest in South-east Norway and in the inland part of

Finmark, and highest in West Norway. The isothermal lines follow the coast-line and lie close together.

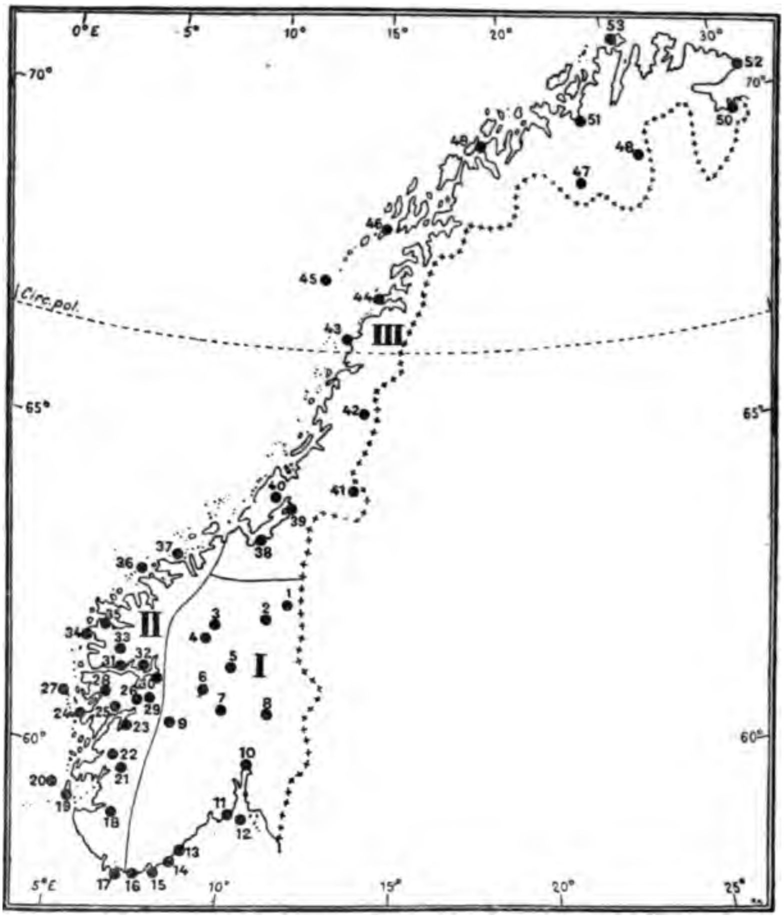

FIG. 2.

I. NORWAY S.E.	ft.
1. Roros	2067
2. Tonset	1634
3. Jerkin	3160
4. Domaas . . .	2110
5. Listad	909
6. Granheim . . .	1812
7. Tonsaasen . . .	2060
8. Hamar	459
9. Fjeldberg . . .	3268
10. Kristiania . . .	82
11. Larvik	59
12. Fœrder	43
13. Torungen . . .	49
14. Grimstad . . .	36
15. Oxo	36
16. Mandal . . .	56

II. NORWAY WEST.	ft.
17. Lindesnœs . . .	62
18. Nedrebo . . .	16
19. Skudenœs . . .	18
20. Utsire	164
21. Roldal	1411
22. Josendal . . .	1182
23. Ullensvang . . .	98
24. Bergen	56
25. Vossevangen . .	177
26. Kleivene . . .	2279
27. Helliso	62
28. Farstveit . . .	354
29. Stondalen . . .	2362
30. Lœrdal	16
31. Flesje	16
32. Sogndal . . .	79
33. Aalhus	715
34. Floro	26
35. Daviken . . .	36
36. Ona	30
37. Kristiansund . .	52

III. NORWAY NORTH.	ft.
38. Trondhjem . . .	36
39. Stenkjæer . . .	26
40. Berge	282
41. Lierne	1463
42. Hatfjelddalen . .	755
43. Rodo	33
44. Bodo	23
45. Rost	26
46. Svolvœr . . .	23
47. Kautokeino . . .	866
48. Karasjok . . .	430
49. Tromso . . .	49
50. Sydvaranger . .	66
51. Alten	43
52. Vardo	33
53. Gjesvær . . .	23

The summer is hottest in South-east Norway, the mean temperature in Christiania being in July, 61°·9; in Hardanger, 58°·3; in the Sognedal, 60°·3; at Karasjok in Finmark, 57°·2.

The summer is coolest on the coast and coldest at Vardö, the most northerly harbour of Norway, where it will be remembered Nansen started in the *Fram* for his celebrated Arctic expedition. Here it is 47°·7. In the mountains (at Roros, 2000 ft.) it is 52°. The July mean of the North Cape 71° N. lat. is 50°·2, and this is again met with on the southernmost point of Iceland 63° 60′ N. lat., showing the comparatively great warmth of Norway.

The annual range of temperature is greatest in the interior, being 55° in Finmark, 45° in South-east Norway, and only 27° on the coast, from Lindesnœs to Vardö.

In South-east Norway the coldest months are December, January, and February, and the winter is most severe in the heart of the country, in the Osterdal, Gudbrandsdal, Valders, and Hallingdal.

At Rorös the minimum is − 48°, and at Tönset − 50°, and mercury frequently freezes.

The severity of the winter in the land districts is only equalled by its duration. Jerkin and Fjeldberg have 200 days with mean temperature below the freezing-point. Christiania and its district are more fortunate, with only 120 to 130 days of great cold. The highest temperatures have been recorded in Christiania, 91°·2, and in Finmark 96°. The highest in West Norway would seem to be those noted at Bergen, 86°, and at Lœrdal on the Sogne Fjord 88°·5.

Along the Norwegian coast the maxima vary from 77° to 79°, on the islands they rarely reach 75°.

Barometer.—For the average of the year the maximum of barometric pressure is over South-east Norway, and the minimum over the Norwegian Sea between Iceland and the North Cape.

In January the maximum pressure of 29·99 ins. is over Central Norway, and the North Cape has the lowest pressure, being 29·64 ins. The minimum pressure seems to lie East of Iceland (29·45 ins.), though a still lower pressure (29·37 ins.) is ascribed to the west of Iceland and south of Greenland.

In July the minimum pressure of 29·80 ins. is over Central Norway, and along the coast there is a zone of maximum pressure of 29·85 ins., while over the Norwegian Sea between Norway and Iceland is a slightly smaller pressure of 29·76 ins.

Then as to *Wind:* as a result of the distribution of atmospheric pressure, it is noticed that the prevailing winds blow off land with curves to the right North-easterly along the Skagerrak; Southerly, along the West Coast, and South-westerly in Northern Norway. In summer the usual winds are from the sea blowing along the coast to the left. In the Skagerrak the winds are most frequently South-west, off Lindesnœs, West, and on the west coast, North. In Northern Norway the prevailing summer winds are North. The force of the wind is greater in winter than in summer, and far greater on the coast than inland. On the coast the average velocity of the wind is from 18 to 22 miles an hour, and storms are frequent. At Ona Lighthouse there are between 60 and 70 stormy days; off Finmark 45 to 62: in the fjords there are frequent calms, and the

number of stormy days does not exceed 5 a year. Calms too are frequent in the interior of the country, over areas of maximum barometric pressure.

The amount of *Cloud* is most on the coast and greatest of all in Finmark, where there are 3 cloudy days for every 1 clear one. In the interior half the days are cloudy and half are clear. The greatest number of clear days are in spring, and generally in April. The number of overcast days is greatest in North Norway, and averages from 18 to 20 per month.

The *Relative Humidity* is greatest in Finmark, where the annual maximum is 82 per cent. At Lœrdal, under the lee of the Jostedalbrœ, it is only 65 per cent, but on the coast generally it is high. In winter the greatest degree of humidity (85 per cent) is found in the cold interior and the smallest on the coast, but in summer the greatest record (80 per cent) is found on the coast and is far less in the interior. At Christiania the mean annual humidity is 60 per cent, but on some days it falls as low as 12 per cent.

Rainy Days and Rainfall.—The largest number of rainy days occur on the coast between Jœdren and Vardö, the least number in South-east Norway. At the North Cape and in the Lofoten Islands and on the west coast between Stad and Sogne Fjord precipitation occurs on 200 days per annum. On the Dovre Fjeld and in the Skagerrak on 100 days. The coast has the greatest number of wet days in January (18·2); in July and August South-eastern Norway has more wet days, viz. 14·8 per month. There are most rainy days in autumn and the first months of winter. Fewest rainy days are noted in all parts of Norway in April.

The annual rainfall is greatest on the coast between Stad and the Sogne Fjord, and amounts to 77 ins., the maximum being at Florö, where it sometimes reaches 90 to 91 ins. In the Lofoten Islands it is 45 ins. In South-east Norway and Finmark it falls to 12 ins. Close to Christiania it is 40 ins., but in Christiania itself it is only 26 ins.

On the coast the greatest rainfall occurs in late autumn and the beginning of winter; in South-east Norway in July and August, the spring having least rain or snow in all parts of Norway. With regard to the proportion of snowy to rainy days, this is naturally largest in the mountain stations of South-east Norway, where they are more than half the total number. On the coast there are but one-fifth or one-sixth snowy days, and in Finmark about as many snowy as rainy days.

The amount of precipitation in a day varies in different regions. In the interior it averages 0·15 in., but on the coast it rises to 0·21 in. The largest daily fall in Eastern Norway occurs in July and August, and amounts to 0·21 in. a day, and it is the same in the Skagerrack in September. In the Bergen district the maximum is in November, and reaches 4·2 ins.

Fogs are common on the coast, but are rare in the interior.

Thunderstorms are not frequent in Norway, and average about 5 a year for the whole country. They are most common on the coast, where they generally occur in winter, and accompany gales of wind from the South-west, West, and North-west. No less than 100 Norwegian churches have been struck by lightning and destroyed in the last 150 years, of which 40 were situated on the coast south of Lofoten.

The snow-line is estimated at 3080 ft. on Seiland near Hammerfest, at 5150 ft. on the Dovre Fjeld, at 4100 to 4900 ft. in the Jotunheim, and 3100 to 4100 ft. on the Jostedalbrœ, and the same on the Folgefond.

The Norwegian mountains, though they lack the varied outlines of the Alpine peaks, are very imposing, rising often in precipices direct from the sea-level in the fjords, and their large covering of snow, owing to the latitude, enhances the effect.

The moist atmosphere is shown in the luxuriant grass growing in the mountains, and often we find what would be bare slabs of granite in Switzerland are covered with verdure in Norway. There is no lack of wild flowers, partly of the British and partly of the Swiss flora, and most picturesque are the turfed roofs of the farm buildings, huts, and sæters which under the damp atmosphere at first become green with moss and grass, but in time are transformed into small gardens of flowers and even of vegetables, and trees of considerable size, usually birch and aspen grow out of them.

Summing up the climate of Norway we see that Eastern and South-eastern Norway have a climate of considerable extremes of cold and of heat, and on the whole are dry, the dryness being due to their position to the lee of the great mountain ranges. The climate here does not materially differ from that of the Continent within the same latitudes. The climate of the Norwegian coast and islands is under the strong influence of the mountains, of the warm currents of the Atlantic Ocean, and of the solar rays, which, though for so long absent from the horizon in winter, are powerful in summer, and shine for many consecutive hours.

The Northman dwelling in this region has much to thank Providence for. In winter the temperature of his country is raised for him by warm water from the Gulf of Mexico, supplied by the Atlantic and introduced into the heart of his land by an elaborate system of fjords. This beautiful arrangement keeps his harbours open all the winter, and enables him to live with comfort in the same latitude in which Franklin perished of cold.

His mountain ranges, lying close to the sea, condense the vapour clouds and supply him with a plentiful rainfall to assist cultivation, and though he may complain of the weary weeks during which the sun never shows his face, he should not forget that when he does appear in full glory it is for a long time together, and thanks to this the food crops ripen as quickly as in South Norway. Moreover, as we before alluded to, the long evenings are illuminated, if faintly, yet in a variety of ways.

Perhaps these periods of gloom tend to contemplation, and give to our Norwegian friend the solemn demeanour which is so marked a characteristic of the race.

Though he is solemn, he is kindly, courteous, intelligent, and honest as the day, as all travellers know, fond of visitors, whom he prides himself on making happy, and, above all, he admires the British nation, learns our language, and loves our race.

Dew-Ponds.—The following scheme for organising a series of meteorological observations intended to throw light upon the supply of dew-ponds has been suggested by a Leeds Committee, consisting of Mr. F. W. Branson, Dr. J. B. Cohen, Mr. Herbert Ingle, Prof. L. C. Miall, and Prof. W. Stroud :—

1. Observations should be made for at least a week, and longer if possible, at two stations, one being a carefully selected dew-pond, the other a low-lying pond in the same neighbourhood.

2. The observations should be taken day and night, at intervals of three hours, and should include the following points:—

(a) Temperature of air.

(b) Temperature of surface and bottom of pond, the depth being noted, and being the same in each case. The bulb of the surface-thermometer to be immersed.

(c) Humidity of air, as measured by dry and wet bulb thermometers.

(d) Amount of dew, to be measured either by parcels of wool (see Wells on *Dew*), or in some other way.

(e) Level of the water of the pond to be measured by an inclined scale dipping into the water. Mr. Ingle has devised a scale which can be read with great ease and considerable accuracy.

(f) A tray containing pond-water to be floated on the surface of the pond, and the loss or gain determined morning and evening by weighing the tray and its contents, the outside of the tray being dried. To secure a tranquil area for the floating tray during a breeze a protective ring of wood or coarse wire gauze, not projecting sensibly above the surface of the water, might be arranged to enclose it. A rough landing-stage would be useful for this and other observations. The observations with a floating tray should be repeated on a low-level pond, and a similar tray containing pure water should be exposed at a spot 30 or 40 ft. away from the dew-pond. All these observations should be simultaneous.

(g) Cloud, mist, rain, sunshine, direction and force of wind, to be noted.

3. The situation, exposure, shape, depth, and superficial area of each pond should be noted. Such part of the margin as can act as a collecting-ground should be measured.

4. Sheep or cattle should not have access to the ponds during the period of observation. If absolutely necessary, a measured volume of water should be transferred every day to a trough for their use, but this is undesirable.

5. Observations on rainfall are most desirable. They cannot be made during the time appointed for observations (a) to (g), which, it is hoped, will be rainless. The best stations for rain-gauges would be at the selected dew-pond, at a spot 30 or 40 ft. away from the dew-pond, and as nearly as possible at the same level, and, lastly, at the low-level pond and at neighbouring stations to windward and leeward during the prevailing winds. It may be necessary, for lack of observers, to employ gauges which will hold the rain of several weeks.

The suggestions which follow relate to the organisation of an observing party.

6. Names to be received of persons who are willing to act, unless unavoidably prevented.

7. A leader to be appointed, who shall fix the date for beginning to observe, and superintend the preparations and observations. A resident in one of the south-eastern counties is to be preferred.

8. A site to be chosen in advance, the consent and co-operation of the landowner being obtained. Fencing of the pond or ponds, and tents for the use of observers, will probably be required.

9. Meteorological instruments to be procured. Mr. F. W. Branson, of the firm of Reynolds and Branson, Leeds, offers to lend some instruments and to obtain any others at cost price.

10. Money will be needed for such expenses as those mentioned above. It is to be expected that each member of the party will meet his own travelling and personal expenses.

11. July or August would probably be the most suitable months for carrying out the observations. Settled weather is considered essential.

12. Meteorologists interested in this inquiry are invited to hold local conferences for the purposes of improving the plan of operations sketched above, and of procuring the help of a sufficient number of observers. Any communications for the Leeds Committee may be addressed to Prof. Miall, the Yorkshire College, Leeds.

MAP SHOWING POSITION OF THE PHENOLOGICAL STATIONS, 1900.

the Names of the Stations see List of Observers, Page 124.

REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1900.

By EDWARD MAWLEY, F.R.H.S., Secretary.

(Plate II.)

[Read February 20, 1901.]

The following changes have taken place in the observing stations since the last Report was issued. No returns were received during the year from Falmouth and Long Ashton in District A; Cheltenham and St. Albans (The Grange) in District D; Glan Conway in District F; Piperstown in District G; and Durham in District I. On the other hand, new stations have been started, or old ones revived, at Tresco (Isles of Scilly) and Gowerton in District A; Skibbereen and Cork in District B; Botley and Bagshot in District C; Watford (Weetwood) and St. Albans (Worley Road) in District D; Hevingham in District E; and Helensburgh in District H.

The averages used for the different plants in Table IV. have been obtained from the actual observations made during the last ten years in all those districts where sufficient observations were available. Those for the remaining districts have also been recalculated, and are as near approximations to the true averages as their scanty records will allow.

TABLE I.—Mean Results, with their Variations from the 10 Years' Average (1891-1900), for the Thirteen Plants in those Districts where there have been sufficient Observations to warrant Comparisons being made.

Years.	Eng. S.W.		Eng. S.		Eng. Mid.		Eng. E.		Eng. N.W.	
	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.
		Days.		Days.		Days.		Days.		Days.
1891	144	+11	144	+10	150	+11	147	+11	150	+ 8
1892	139	+ 6	138	+ 4	144	+ 5	143	+ 7	147	+ 5
1893	118	- 15	122	- 12	125	- 14	123	- 13	128	- 14
1894	126	- 7	130	- 4	135	- 4	127	- 9	137	- 5
1895	139	+ 6	138	+ 4	141	+ 2	138	+ 2	144	+ 2
1896	125	- 8	128	- 6	132	- 7	130	- 6	134	- 8
1897	130	- 3	132	- 2	136	- 3	132	- 4	142	0
1898	133	0	135	+ 1	138	- 1	136	0	141	- 1
1899	136	+ 3	136	+ 2	141	+ 2	138	+ 2	145	+ 3
1900	142	+ 9	141	+ 7	144	+ 5	143	+ 7	152	+10
Mean	133	...	134	...	139	...	136	...	142	...

Explanation of the Dates in the Tables.

1– 31 are in January.		182–212 are in July.	
32– 59	,, February.	213–243	,, August.
60– 90	,, March.	244–273	,, September.
91–120	,, April.	274–304	,, October.
121–151	,, May.	305–334	,, November.
152–181	,, June.	335–365	,, December.

The Winter of 1899–1900.

Taken as a whole, this was a cold winter in all parts of the British Isles. December and February were both cold months, while the mean

temperature of January proved, on the other hand, almost everywhere rather high. Except in Scotland west and north, the total rainfall was in excess of the average. The record of bright sunshine was unusually good in Ireland and Scotland, but fell short of the mean in all the English districts.

The winter corn, although sown unusually late in the autumn, germinated so quickly and made such good growth that the frosts in the middle of December were welcomed as giving it a timely check. Throughout January the young wheat presented a most promising appearance, but was less favoured by the weather in February owing to the persistent rainfall of that month. The cultivation of the land for spring corn was carried on with but little interruption, until about the middle of January, but after that time the soil was mostly too wet with rain and melted snow to allow of any sowing, worth mentioning, being done during the rest of the season. For the sake of the pastures, the mild weather in January proved especially acceptable to the farmers, as the crop of swedes in the previous year had been so deficient.

In most districts many garden plants continued in flower until about the end of the first week in December, and in the warmest parts of our islands such unseasonable flowers as roses and mignonette could be gathered as late as the middle of February.

Several observers note the abundant catkins on the hazel towards the end of the season. The fertile flowers appeared everywhere on the hazel behind their average time, but the departures from the mean dates were considerably greater in the colder districts than in the southern half of England and Ireland, owing to the greater cold experienced in those districts as compared with other parts of the British Isles.

The song-thrush was first heard to sing after the beginning of the year, 3 days earlier than usual.

The honey-bee was first observed to visit flowers 6 days later than its mean date.

The Spring.

March was everywhere a very cold month, but during the rest of the spring quarter the departures from the average in mean temperature were in no way remarkable. In all three months there was in most districts a rather deficient rainfall. With the exception of the north-west of England and the north of Scotland, there was a scanty record of sunshine.

The ground continued so wet and cold during March and the early part of April, that little spring corn was put in until about the middle of the latter month—a singularly late date. From this time, however, rapid progress was made, as the soil remained for some weeks in an excellent condition for planting. The winter corn crops, owing doubtless to the firm roothold they had obtained of the ground in January, do not appear to have suffered so much from the cold and sodden state of the land as might have been expected. In the pastures and meadows the grass made scarcely any progress until the third week in April, when a welcome change to warmer conditions both above and below ground took place. Although this warm spell lasted only about a week, it was

of considerable service to vegetation generally, and a great contrast to the cold and gloomy weather which had previously prevailed. The rains towards the end of May also favoured the growth of the grass, but came too late to be of any material help to the hay crop in the southern districts of England.

In the gardens everything was very backward, and seeds germinated slowly owing to the coldness of the ground and the scanty supply of sunshine. The fruit trees blossomed profusely, and notwithstanding the cold winds there was in most districts a satisfactory set of fruit.

There was an unusual show of bloom on the blackthorn and other early flowering wild shrubs and trees.

All the spring plants were backward in coming into bloom, and appear to have been uniformly late throughout the season in all parts of the country. The coltsfoot was 12 days late, the wood anemone 10 days late, the blackthorn 11 days late, the garlic hedge mustard 9 days late, the horse-chestnut 8 days late, and the hawthorn 9 days late.

Most of the spring migrants were also behind their mean dates in visiting these islands. The swallow was 4 days late, the cuckoo 2 days late, and the nightingale 2 days late, while, according to the returns sent in, the flycatcher arrived at its average date.

The wasp made its appearance 9 days late, the small white butterfly 8 days late, and the orange-tip butterfly 7 days late.

The Summer.

In all parts of the kingdom this was a warm summer, but only in July could the heat be regarded as exceptional. During that month the mean temperature was from 4°·0 to 4°·3 above the average throughout the southern, midland, and eastern districts of England. The fall of rain varied considerably, but in most districts was in excess of the mean for the season. Except in Scotland, this was an unusually sunny quarter, and especially was this the case throughout the whole of the southern half of England.

The cereals continued to make satisfactory progress during June, and to the spring corn the frequent rains of that month were particularly favourable. At the end of June the harvest promised to be a very late one indeed, but on July 10 came the surprise of the season, namely a sudden change to extreme heat, which lasted until the end of the month, or for exactly three weeks. This unexpected change upset all previous calculations, and the harvest instead of being a very late one began, if anything, rather earlier than usual. Indeed, during the third week in August, harvest was general throughout the greater part of England. The extremely rapid way in which the corn crops ripened could not fail to be detrimental to the yield and quality of the grain. In the earlier districts the harvest began under unfavourable conditions, owing to the frequent interruptions caused by rain. The gales and heavy rains in the early part of August did much damage to the standing corn in many parts of the country, by causing the straw to become laid and twisted.

In many places the corn harvest followed closely upon the ingathering of the hay, owing to the grass having been left standing in the fields long after it was ready to cut, with a view to its obtaining the

benefit of the June rains. A heavier crop was thus secured, but at the expense of the quality of the hay. These remarks do not apply to Scotland and Ireland or the northern districts of England, where the crop of grass proved, as a rule, an abundant one. The pastures were freshened by the June rains, but except in the cooler districts of these islands no satisfactory growth was made until after wet weather had

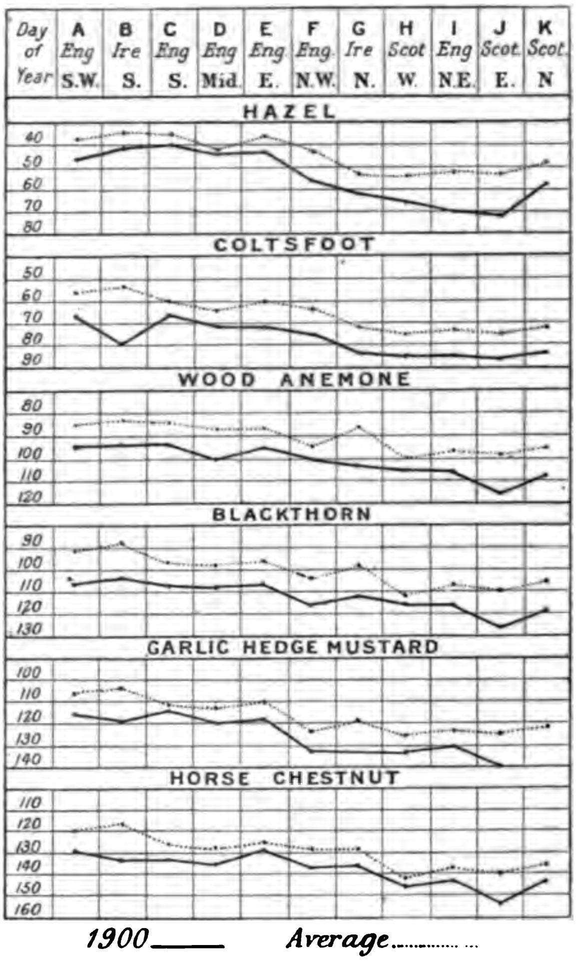

FIG. 1.

set in in August. In Ireland the grass made splendid growth during the whole season.

Turnips and swedes passed through many vicissitudes before reaching maturity. Owing to the dry spring the seed had in many cases to be re-sown several times before a satisfactory plant could be obtained. Good growth was made in June, but on the other hand the July heat and drought proved almost disastrous. Ultimately the August rains

and the subsequent warm autumn prevented a small crop from becoming one of the smallest on record.

This was not a favourable year for potatoes. The dry weather in July checked their growth, and the heavy rains which followed brought on disease—particularly in Ireland, where the yield is estimated to have been about three-quarters of a ton per acre under average.

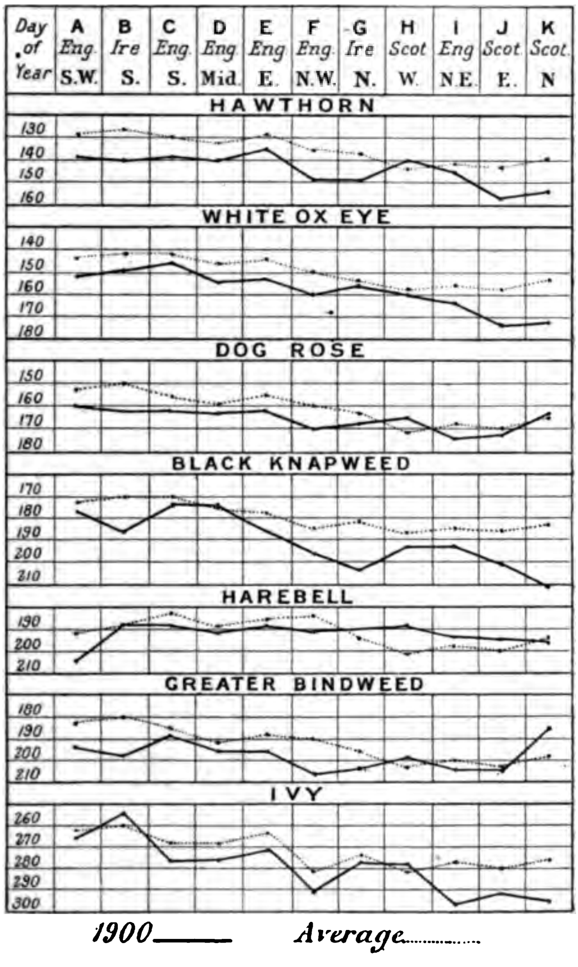

FIG. 2.

The long period of hot and dry weather in July proved very trying in the garden in all the drier districts, and was more keenly felt on account of the partial drought in the spring, so that the change to moister conditions in August was very acceptable. The gales of August 3 and 4 proved very destructive by uprooting plants not firmly staked, and by blowing down a large quantity of fruit from the trees. These gales also did much damage to the foliage of trees in some parts of the south and south-west of England.

There were but few butterflies until late in the season, when they became, for the time of year, unusually numerous. One noteworthy feature of the summer was the unusual freedom of the oak and other trees from the attacks of caterpillars.

All the wild plants on the list which flowered during the summer blossomed unusually late. The white ox-eye was 8 days late, the dog-rose 5 days late, the black knapweed 11 days late, the harebell 1 day late, and the greater bindweed 5 days late.

The meadow-brown butterfly first made its appearance 4 days late.

The Autumn.

Throughout very nearly the whole of the British Isles the temperature ruled high during each of the three months of this quarter, but in no month was the variation from the average in mean temperature in any way remarkable. In Scotland and Ireland this proved a wet autumn, but in all the English districts there was a deficient rainfall. There was an exceptionally good record of sunshine in the southern half of these islands, but in the other districts the departures from the mean were, as a rule, not nearly as marked.

No sooner was the corn harvest approaching completion in the south than a beginning was made in the later districts. In each case showery weather marred the early part of the ingathering, but the bulk of the crop was secured under the most favourable conditions. Taking the country as a whole, only a limited portion of the corn was not well secured; for although there was at times a good deal of rain, yet the wet weather was nowhere persistent—if we except the late districts in Scotland.

When once the land had become sufficiently softened by rain at the end of September, ploughing was proceeded with without any serious hindrance; and, as is usual after a long period of dry weather followed by rain, the land was in splendid condition for cultivation. In the middle of October, a good deal of wheat was sown, and in as satisfactory a seed-bed as could well be wished. On the other hand, in Scotland and Ireland the weather continued most unpropitious, owing to the continuous and heavy rainfall.

Seldom has there been so fine a display of flowers in the garden as during this autumn. In most places even such tender plants as dahlias continued in flower until cut off by frost in the middle of November. Notwithstanding the dry weather, green vegetables in the kitchen garden, favoured by the genial warmth of the soil, made excellent growth. It was not, however, until November was well advanced that the ground had become moistened to a sufficient depth to allow of the transplanting of fruit and other trees.

There was a remarkable display of wild fruits of all kinds—including hips, haws, acorns, beechmast, and blackberries. Wasps were numerous in most districts. The humming-bird hawkmoth and cloudy yellow butterfly also made their appearance early in the season in unusual numbers.

The ivy flowered 9 days later than its average date.

Swallows, as a rule, left this country about 1 day earlier than their usual time.

According to the preliminary statement for Great Britain issued by the Board of Agriculture, the estimated yield of wheat fell short of the average for the previous 10 years by 1·62 bushels per acre, barley by 2·19 bushels per acre, and oats by 0·86 bushels per acre. The crop of wheat gave the smallest average yield since 1895, while that of barley was the smallest since the dry year of 1893. Taking the country as a whole, the corn harvest began one day in advance of the mean date for the previous 9 years. Hay was generally a small crop in the south of England, about average in the northern counties of England, and over average in Scotland and Ireland. Turnips and swedes were generally under average, but there was in most districts a heavy crop of mangolds. Potatoes were, as a rule, deficient both in yield and quality. Beans and peas were nearly average. The yield of hops was very poor. In Ireland flax proved a singularly good crop.

There was almost everywhere an abundant yield of fruit. Apples, plums, raspberries, currants, gooseberries, and strawberries were all over average; but in the case of apples the fruit was, as a rule, small. The only deficient crop appears to have been that of pears, which were in most districts under average both in yield and size.

The Year.

During the greater part of the winter and spring the weather proved cold and sunless, but in the summer and autumn the temperature was, as a rule, high and there was an unusually good record of bright sunshine. As affecting vegetation, the two most noteworthy features of the Phenological year were the cold, dry, and gloomy character of the spring months, and the great heat and drought in July. Throughout the whole of the flowering season wild plants came into blossom much behind their average dates, indeed, later than in any year since 1891. Such spring migrants as the swallow, cuckoo, and nightingale were also later than usual in reaching these shores. Taking the British Isles as a whole, the crops of wheat, barley, and oats were all more or less under average; the yield of hay was poor in the southern half of England, but elsewhere varied from a fair to an abundant crop. Turnips and swedes were almost everywhere deficient, but there was a heavy crop of mangolds. Potatoes were generally under average. This was a bountiful year as regards fruit, the yield of apples, plums, and all the small fruits being remarkably good.

Observers' Notes.

December 1899.—*Mawnan* (A)—1st. Twenty-nine flowers out in our garden alone. *Glendalough* (B)—6th. Nasturtiums near house as yet untouched by frost. *Churt Vicarage* (C)—8th. Roses, auriculas, primroses, etc., still in flower in my garden until destroyed by last night's frost. *Ross* (D)—During the first week of the month occurred suddenly a severe frost which killed pentstemons, veronicas, and winter-greens outright. *Brunstead* (E)—Gathered several good mushrooms. 10th. Mignonette and sweet-peas still in flower. 14th. Many snipe and wild-fowl about. *Clenchwarton* (E)—9th. Roses in flower out of doors. *Cronkbourne* (F)—2nd. Dahlias killed by frost. *Sulby* (F)—10th. Auriculas in flower in open ground. *Lilliesleaf* (I)—After severe weather large flocks of wheatears, bramblings, and snow-buntings.

TABLE II.—LIST OF THE STATIONS WITH THE NAMES OF THE OBSERVERS.

Station.	County.	Height above Sea-level.	Observer.
A		Ft.	
1. Tresco . .	Scilly . .	5	J. Jenkin.
2. Marazion . .	Cornwall . .	40	F. W. Millett.
3. Mawnan . .	Cornwall . .	200	Miss R. Barclay.
4. Liskeard . .	Cornwall . .	400	S. W. Jenkin, C.E.
5. Altarnon . .	Cornwall . .	600	C. U. Tripp, M.A., F.R.Met.Soc.
6. Tiverton . .	Devon . .	270	Miss M. E. Gill.
7. Westward Ho .	Devon . .	130	Miss Patterson.
8. Barnstaple . .	Devon . .	90	T. Wainwright.
9. Sidcot . .	Somerset . .	200	W. F. Miller.
10. Clifton . .	Gloucester .	300	G. C. Griffiths, F.E.S.
11. Penarth . .	Glamorgan .	120	G. A. Birkenhead.
12. Bridgend . .	Glamorgan .	90	H. J. Randall, Junr.
13. Gowerton . .	Glamorgan .	...	Rev. R. Jackett.
14. Castleton . .	Monmouth .	80	F. G. Evans, F.R.Met.Soc.
15. Bassaleg . .	Monmouth .	125	W. J. Grant, F.R.H.S.
16. St. Arvans . .	Monmouth .	360	Miss M. Peake.
17. St. Davids . .	Pembroke .	220	W. P. Propert, LL.D., F.R.Met.Soc.
18. Aberystwith .	Cardigan . .	30	J. H. Salter, D.Sc.
B			
19. Skibbereen . .	Cork . .	30	J. J. Wolfe.
20. Cork . . .	Cork . .	100	J. Griffin.
21. Killarney . .	Kerry . .	100	Ven. Archdeacon Wynne, D.D.
22. Cappagh . .	Waterford .	140	R. J. Ussher.
23. Ferns . . .	Wexford . .	260	G. E. J. Greene, M.A., D.Sc., F.L.S.
24. Glendalough .	Wicklow . .	460	Mrs. W. Wynne.
25. Geashill . .	King's County .	280	Rev. Canon Russell.
C			
26. Bembridge . .	Isle of Wight .	80	C. Orchard, F.R.H.S.
27. Blandford . .	Dorset . .	270	J. C. Mansell-Pleydell, F.G.S., F.L.S.
28. Buckhorn Weston	Dorset . .	290	Miss H. K. H. D'Aeth.
29. Havant . .	Hants . .	30	H. Beeston.
30. Botley . .	Hants . .	30	Lady Jenkyns.
31. Breamore . .	Hants . .	...	S. Bramley.
32. Muntham . .	Sussex . .	250	P. S. Godman, F.Z.S.
33. Dover. . .	Kent . .	150	F. D. Campbell.
34. Chiddingfold .	Surrey . .	230	Vice-Admiral Maclear, F.R.Met.Soc.
35. Winterfold . .	Surrey . .	580	R. Turvey.
36. Coneyhurst . .	Surrey . .	600	J. Russell.
37. Churt Vicarage .	Surrey . .	350	Rev. A. W. Watson.
37. Churt . . .	Surrey . .	300	C. Criddle.
38. Oxshott . .	Surrey . .	210	W. H. Dines, Pres.R.Met.Soc.
39. Bagshot . .	Surrey . .	230	W. Burgess.
40. East Molesey .	Surrey . .	40	Miss R. Follett.
41. Weston Green .	Surrey . .	30	H. T. Potter.
42. Marlborough .	Wilts . .	480	E. Meyrick.
D			
43. Oxford . .	Oxford . .	200	F. A. Bellamy, F.R.Met.Soc.
44. Beckford . .	Gloucester .	120	F. Slade, F.R.Met.Soc.
45. Wealdstone .	Middlesex .	180	G. E. Eland.
46. Chesham . .	Bucks . .	300	Miss G. Keating.
47. Watford (The Platts)	Herts . .	240	Mrs. G. E. Bishop.
47. Watford (Weetwood)	Herts . .	270	Mrs. J. Hopkinson.

TABLE II.—LIST OF THE STATIONS WITH THE NAMES OF OBSERVERS—*Continued.*

STATION.	COUNTY.	Height above Sea-level.	OBSERVER.
		Ft.	
48. St. Albans	Herts	300	H. Lewis.
49. Berkhamsted	Herts	400	Mrs. E. Mawley.
50. Harpenden	Herts	370	J. J. Willis.
51. Ross	Hereford	210	H. Southall, F.R.Met.Soc.
52. Leominster	Hereford	220	J. H. Arkwright.
53. Farnborough	Warwick	520	Miss D. J. G. Prater.
54. Ullenhall	Warwick	340	Mrs. Coldicott.
55. Northampton	Northampton	320	H. N. Dixon, M.A., F.L.S.
56. Thornhaugh	Northampton	90	Rev. H. H. Slater.
57. Churchstoke	Montgomery	550	P. Wright, F.R.Met.Soc.
58. Thurcaston	Leicester	250	Rev. T. A. Preston, M.A., F.R.Met.Soc.
59. Beeston	Notts	210	G. Fellows.
60. Hodsock	Notts	60	Miss Mellish, F.R.H.S.
61. Macclesfield	Cheshire	500	J. Dale.
62. Belton	Lincoln	200	Miss F. H. Woolward.
63. Sheffield	Yorks (W.R.)	450	Miss E. F. Smith.
64. Horbury	Yorks (W.R.)	100	J. Burton.
65. Ripley	Yorks (W.R.)	240	Rev. W. T. Travis.
E			
66. Broxbourne	Herts	120	Rev. H. P. Waller.
67. Hatfield	Herts	300	T. Brown.
68. Hertford	Herts	140	W. Graveson.
69. Sawbridgeworth	Herts	350	H. S. Rivers.
70. Hitchin	Herts	220	A. W. Dawson, M.A.
71. Odsey (Ashwell)	Cambridge	260	H. G. Fordham.
72. Bocking	Essex	240	H. S. Tabor, F.R.Met.Soc.
73. Lexden	Essex	90	S. F. Hurnard and Miss Carver.
74. Sproughton	Suffolk	30	Rev. A. Foster-Melliar.
75. Market Weston	Suffolk	150	Rev. E. T. Daubeney.
76. Tacolneston	Norfolk	190	Miss E. J. Barrow.
77. Brundall	Norfolk	70	A. W. Preston, F.R.Met.Soc.
78. Brunstead	Norfolk	30	Rev. M. C. H. Bird.
79. Hevingham	Norfolk	...	Major Marsham.
80. Clenchwarton	Norfolk	10	Miss E. M. Stevenson.
81. Peterborough	Northampton	30	J. W. Bodger.
F			
82. Palé	Merioneth	600	T. Ruddy.
83. Alderley Edge	Cheshire	300	W. H. Pepworth.
84. Ambleside	Westmoreland	260	Miss M. L. Hodgson.
85. Cronkbourne	Isle of Man	110	A. W. Moore and J. Murphy.
86. Orry's Dale	Isle of Man	70	Miss C. M. Crellin.
87. Sulby	Isle of Man	80	H. S. Clarke, F.E.S.
G			
88. Ardgillan	Dublin	210	J. Woodward.
89. Edgeworthstown	Longford	270	J. M. Wilson, M.A.
90. Westport	Mayo	10	J. M. McBride.
91. Loughbrickland	Down	350	Rev. Canon Lett.
92. Saintfield	Down	310	Rev. C. H. Waddell, M.A.
93. Antrim	Antrim	70	Rev. W. S. Smith.
94. Altnafoyle	Londonderry	450	T. Gibson.
95. Ramelton	Donegal	200	Miss K. Swiney.
H			
96. New Galloway	Kirkcudbright	450	T. R. Bruce.
97. Jardington	Dumfries	100	J. Rutherford.

TABLE II.—List of the Stations with the Names of Observers—*Continued.*

Station	County.	Height above Sea-level.	Observer.
		Ft.	
98. Helensburgh	Dumbarton	100	Miss Muirhead.
99. Port Ellen	Isle of Islay	10	T. F. Gilmour.
100. Duror	Argyll	20	R. Macgregor.
I			
101. Doddington	Lincoln	90	Rev. R. E. Cole.
102. Thirsk	Yorks (N.R.)	120	A. B. Hall.
103. East Layton	Yorks (N.R.)	570	Mrs. E. O. Maynard Proud.
104. Willington	Durham	390	Rev. W. T. Wyley.
105. Corbridge-on-Tyne	Northumberland	200	A. W. Price.
106. Blyth	Northumberland	20	S. Dunnett.
107. Lilliesleaf	Roxburgh	530	Miss C. M. D. Sprot.
108. Chirnside	Berwick	400	C. Stuart, M.D.
J			
109. Kirriemuir	Forfar	250	T. M. Nicoll.
110. Aberdeen	Aberdeen	40	P. Harper.
111. Newmill	Banff	350	J. Ingram.
K			
112. Invermoidart	Inverness	60	S. M. Macvicar.
113. Roshven	Inverness	40	H. Blackburn.
114. Beauly	Inverness	60	A. Birnie.
115. Dingwall	Ross	10	J. P. Smith, M.D.
116. Inverbroom	Ross	50	Lady Fowler.
117. Watten	Caithness	150	Rev. D. Lillie.

The numbers before the names of the stations refer to their position on the map of the stations, Plate II.

January 1900.—*St. Arvans* (A)—22nd. Winter aconite in flower. *Aberystwith* (A)—21st. Missel-thrush first heard. *Glendalough* (B)—Tea and china roses still in flower. *Bembridge* (C)—13th. Winter aconite in flower. *Churt Vicarage* (C)—29th. Found a robin's nest with three eggs in it. *Weston Green* (C)—9th. Thrush's eggs found on lawn. *Watford* (*The Platts*) (D)—24th. Winter aconite in flower. *Berkhamsted* (D)—23rd. Winter aconite in flower—one day later than its average date in the previous eleven years. *Lexden* (E)—23rd. Winter aconite in flower. *Clenchwarton* (E)—13th. Winter aconite in flower. *Cronkbourne* (F)—10th. Rhododendrons in full bloom. *Edgeworthstown* (G)—18th. Winter aconite in flower.

February.—*Mawnan* (A)—Until cut by the frost in the second week of February, mignonette had been in full flower all the winter. *Aberystwith* (A)—5th. Winter aconite in flower. 24th. Frog spawn first seen. *Skibbereen* (B)—Snow on ground 10th to 21st, during which time many song-thrushes, redwings, fieldfares, blackbirds, starlings, etc., perished. *Glendalough* (B)—6th. Frost destroyed ivy geraniums, and other delicate plants hitherto uninjured. *Hodsock* (D)—19th. Winter aconites in flower. Owing probably to December frosts, a great deal of dead wood on tea-roses. *Ripley* (D)—15th. A pied wagtail took shelter in my covered yard; the earliest date I have ever seen one here. *Hitchin* (E)—1st. Heavy snowstorm did considerable damage to shrubs. *Tacolneston* (E)—An extraordinary quantity of catkins on hazel. *Ambleside* (F)—27th. Catkins on hazels magnificent—the woods for miles are quite yellow

TABLE III.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1900.

STATION.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse-chestnut.	Hawthorn.	White Ox Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.
A													
Tresco . .	...	...	...	...	...	...	143	...	...	...	...	...	...
Marazion . .	54	56	...	102	...	...	127	154	156	192	...	180	271
Mawnan . .	55	102	...	95	...	131	141	154	164	176	...	...	263
Liskeard . .	56	65	107	103	...	...	142	...	...	...	...	...	...
Altarnon . .	57	92	111	115	116	139	153	156	188	197	205	230	280
Tiverton . .	51	74	101	100	113	132	*121*	141	151	162	...	197	...
Westward Ho .	60	...	...	104	126	132	143	161	153	203	...	...	297
Barnstaple . .	24	44	91	100	112	123	141	151	162	177	204	189	264
Sidcot . . .	32	62	75	111	110	121	132	149	151	...	...	200	240
Clifton . .	...	...	99	111	...	128	138	...	153	...	...	...	...
Bridgend . .	56	71	87	111	117	140	147	158	164	172	...	198	279
Gowerton . .	...	50	...	...	...	...	...	...	...	...	...	...	...
Castleton . .	32	68	85	105	114	120	133	149	163	172	..	181	264
Bassaleg . .	51	55	93	107	110	119	134	139	158	166	...	174	263
St. Arvans . .	29	71	95	110	116	129	142	152	161	171	...	...	254
St. Davids . .	...	58	...	118	...	...	127	149	...	179	...	191	...
Aberystwith .	...	...	95	94	...	129	141	...	157	171	...	...	256
B													
Skibbereen . .	35	...	94	96	...	133	136	147	162	199	...	201	...
Cork . . .	51	...	...	...	...	...	...	...	...	...	...	...	...
Killarney . .	21	70	97	100	117	120	132	145	161	196	189	190	254
Ferns . . .	56	90	81	98	...	140	135	146	164	174	187	189	263
Glendalough .	20	*105*	99	104	121	136	149	150	...	...	...	...	...
Geashill . .	62	...	92	112	...	130	149	157	...	178	...	215	249
C													
Bembridge . .	28	25	...	102	114	122	128	135	161	...	...	...	...
Blandford . .	23	45	83	108	121	138	143	143	...	166	171	...	296
Buckhorn Weston	36	47	99	109	108	137	136	145	151	169	...	169	293
Havant . .	34	...	99	105	103	...	133	147	159	168	...	169	273
Botley . .	56	71	86	107	114	134	138	146	160	177	207	206	300
Breamore . .	60	...	...	...	...	...	...	...	...	...	...	...	...
Muntham . .	20	73	88	104	112	130	135	149	162	...	...	...	286
Dover . . .	...	...	...	95	...	...	146	...	166	181	...	...	276
Chiddingfold .	55	71	94	108	116	132	141	147	164	165	198	195	263
Winterfold . .	54	...	102	107	...	143	155	170	...	...	197	...	313
Coneyhurst . .	57	87	90	113	*132*	137	141	146	162	182	181	157	235
Churt Vicarage .	28	76	99	112	113	134	141	146	164	174	177	209	...
Churt . . .	9	90	96	110	100	122	126	132	161	...	...	198	271
Oxshott . .	64	90	...	109	121	135	140	...	...	...	...	...	288
Bagshot . .	...	...	104	112	...	128	141	138	162	171	...	198	268
East Molesey .	...	...	...	99	124	127	139	146	167	*233*	195	..	...
Weston Green .	55	...	...	110	122	126	*128*	...	...	...	...	...	260
Marlborough .	23	66	89	112	117	137	144	146	165	181	174	196	255
D													
Oxford . .	...	...	...	99	106	126	143	...	163	...	...	181	265
Beckford . .	50	79	90	103	112	126	132	135	159	167	191	175	264
Wealdstone . .	...	84	104	111	...	128	132	155	161	...	*230*	...	...
Chesham . .	28	68	105	...	109	139	145	140	...	197	...	197	301
Watford (The Platts)	24	..	104	109	115	127	141	158	160	...	...	...	...
Watford (Weetwood)	32	...	...	99	106	130	135	153	162	179	178	206	264
St. Albans . .	*70*	...	108	...	...	...	144	...	...	...	...	...	...

TABLE III.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1900—*Continued.*

Station	Hazel	Coltsfoot	Wood Anemone	Blackthorn	Garlic Hedge Mustard	Horse-chestnut	Hawthorn	White Ox Eye	Dog Rose	Black Knapweed	Harebell	Greater Bindweed	Ivy
Berkhamsted	55	58	103	111	122	143	150	148	159	176	197	185	280
Harpenden	54	58	105	104	112	135	136	150	161	...	...	...	...
Ross	21	58	95	109	109	127	127	...	160	169	191	202	256
Leominster	15		98	105	...	140	144	...	...	...	...	188	289
Farnborough	24	64	103	114	128	139	138	160	158	...	201	...	282
Ullenhall	27	72	95	99	104	125	121	146	150	160	191	198	...
Northampton	53	64	95	112	124	131	140	158	166	176	187	206	260
Thornhaugh	54	76	86	101	132	137	139	...	...	...	...	...	285
Churchstoke	56	90	100	112	131	141	148	...	171	...	206	*217*	...
Thurcaston	72	72	106	111	121	140	141	155	164	176	191	207	268
Beeston	55	72	...	113	132	142	143	162	169	171	165	...	...
Hodsock	54	73	103	112	117	132	138	156	166	178	197	180	266
Macclesfield	47	77	104	114	139	150	153	162	172	187	189	192	275
Belton	55	67	96	109	122	134	143	...	...	...	...	...	...
Sheffield	63	...	93	...	...	139	151	...	182	...	193	204	302
Horbury	52	62	104	118	132	*178*	142	158	174	168	196	203	282
Ripley	31	...	94	122	136	144	...	...	...	...	...	...	...
E													
Hatfield	...	...	105	111	...	128	131	...	161	199	190	205	...
Hertford	53	76	87	103	111	133	130	146	161	184	189	201	273
Sawbridgeworth	53	71	...	109	113	134	146	157	162	...	...	179	280
Hitchin	...	...	94	111	110	132	129	...	161	...	181	...	...
Odsey (Ashwell)	26	...	...	106	...	...	128	...	156	...	...	...	267
Bocking	15	71	102	112	115	125	133	160	161	182	195	209	250
Lexden	59	...	99	109	121	127	132	146	160	169	177	179	...
Sproughton	19	68	79	110	119	126	130	145	162	175	...	...	...
Market Weston	55	73	100	110	117	130	132	152	162	176	199	194	261
Tacolneston	...	63	100	111	114	125	138	...	163	171	...	...	274
Brundall	53	...	100	112	126	127	131	*136*	162	202	...	...	272
Brunstead	43	...	105	113	126	134	149	157	167	203	193	199	270
Hevingham	...	...	74	...	...	...	149	...	...	...	...	...	...
Clenchwarton	...	54	...	98	121	127	142	...	164	200	...	...	283
Peterborough	57	91	98	90	126	*140*	125	...	...	...	...	...	284
F													
Palé	56	69	112	112	137	143	152	161	166	185	191	222	307
Alderley Edge	42	70	94	...	135	136	150	159	174	...	190	...	...
Ambleside	58	...	91	113	125	146	147	...	...	...	...	196	284
Cronkbourne	...	...	103	...	130	127	148	...	...	207	*209*	203	283
Orry's Dale	68	87	...	122	...	...	...	...	...	...	...	...	...
G													
Ardgillan	63	71	103	112	...	137	148	153	*183*	205	...	206	279
Edgeworthstown	...	*115*	114	113	...	136	...	...	168	...	...	...	...
Westport	...	...	...	109	...	...	137	...	168	...	...	...	270
Loughbrickland	*83*	104	107	121	...	146	153	157	166	201	...	200	273
Saintfield	55	71	97	108	...	136	148	162	173	...	...	...	...
Antrim	69	91	...	113	...	135	146	156	...	...	...	207	288

TABLE III.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1900—*Continued.*

STATION.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse-chestnut.	Hawthorn.	White Ox Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bind-weed.	Ivy.
Altnafoyle	56	71	98	103	...	135	148	...	167	206	...	...	...
Ramelton	*88*	88	92	...	...	132	149	148	164	205	...	...	...
H													
New Galloway	60	...	112	123	...	153	153	163	169	...	188	...	...
Jardington	69	93	102	115	...	143	150	...	166	202	190	...	...
Helensburgh	59	90	111	116	133	138	125	...	...	...	...	...	...
Port Ellen	83	91	...	108	...	...	...	...	...	...	196	199	275
Duror	62	64	94	116	...	...	132	157	161	184	182	...	283
I													
Doddington	59	98	100	114	124	128	143	...	164	...	...	...	268
Thirsk	33	...	103	110	122	143	126	163	166	184	184	181	301
East Layton	81	87	*140*	127	...	140	...	...	...	...	...	...	...
Willington	84	79	106	119	127	146	151	162	173	...	190	195	305
Corbridge-on-Tyne	67	88	107	119	123	148	152	159	176	202	191	207	305
Blyth	...	62	99	112	132	144	148	159	163	192	190	207	...
Lilliesleaf	*119*	...	...	*93*	...	...	...	183	192	...	211	...	...
Chirnside	94	96	121	110	152	152	150	156	181	*171*	201	232	305
J													
Kirriemuir	...	93	...	*155*	...	...	...	...	167	...	184	...	...
Aberdeen	...	96	117	...	...	157	159	186	185	...	205	...	298
Newmill	71	73	115	126	140	148	157	161	165	201	*172*	204	284
K													
Invermoidart	55	...	...	...	...	...	...	...	...	...	...	...	279
Roshven	*35*	77	106	117	...	142	150	168	166	206	...	186	291
Beauly	59	90	115	128	...	150	156	164	165	201	192	...	...
Dingwall	61	73	102	112	...	141	150	163	165	...	201	...	314
Inverbroom													
Watten	...	91	...	...	...	...	162	191	...	225	...	...	...

The dates in *italics* have not been taken into consideration when calculating the means given in Table IV.

with them. *New Galloway* (H)—20th. Winter aconite in flower. *Lilliesleaf* (I)—Many birds died after severe snowstorm at the end of the month. *Chirnside* (I)—28th. Winter aconite in flower. *Watten* (K)—24th. Winter aconite in flower.

MARCH.—*Marazion* (A)—4th. Wheatear first seen. *Mawnan* (A)—31st. Humming-bird hawkmoth seen. *Liskeard* (A)—11th. Redwings last seen. *Bridgend* (A)—17th. Wheatear first seen. *Bembridge* (C)—4th. Prunus Pissardi in flower. *Havant* (C)—31st. Cuckoo heard by a friend in Rockingham Park, Northants. *Breamore* (C)—12th. Caught a humming-bird hawkmoth. *Hodsock* (D)—No green leaves at all were to be seen this month except on gooseberries. *Lexden* (E)—22nd. Wryneck first heard. *Market Weston* (E)—Some summer

TABLE IV.—Mean Dates (Day of Year) for the First Flowering of Plants in 1900, and their Variations from the Ten Years' Average (1891-1900).

Plants.	A England, S.W.			B Ireland, S.			C England, S.			D England, Mid.		
	1900.	Average for 10 Years.	Variation from Average.	1900.	Average for 10 Years.	Variation from Average.	1900.	Average for 10 Years.	Variation from Average.	1900.	Average for 10 Years.	Variation from Average.
Hazel	46	38	+ 8	41	*35*	+ 6	40	36	+ 4	43	42	+ 1
Coltsfoot	67	56	+11	80	*53*	+27	67	60	+ 7	71	64	+ 7
Wood Anemone	94	85	+ 9	93	*82*	+11	94	84	+10	100	88	+12
Blackthorn	106	91	+15	102	*88*	+14	107	97	+10	109	99	+10
Garlic Hedge Mustard	115	106	+ 9	119	*103*	+16	114	111	+ 3	120	114	+ 6
Horse-chestnut	129	120	+ 9	132	*117*	+15	132	126	+ 6	135	129	+ 6
Hawthorn	139	129	+10	140	*126*	+14	139	130	+ 9	140	132	+ 8
White Ox Eye	151	144	+ 7	149	*141*	+ 8	145	141	+ 4	153	148	+ 5
Dog Rose	160	153	+ 7	162	*150*	+12	162	156	+ 6	164	159	+ 5
Black Knapweed	178	173	+ 5	187	*170*	+17	173	170	+ 3	175	176	− 1
Harebell	205	191	+14	188	*188*	Av.	188	182	+ 6	191	190	+ 1
Greater Bindweed	193	183	+10	199	*180*	+19	189	186	+ 3	195	191	+ 4
Ivy	266	263	+ 3	255	*260*	− 5	277	269	+ 8	276	270	+ 6
Mean for the 13 Plants	142	133	+ 9	142	*129*	+13	141	134	+ 7	144	139	+ 5

Plants.	E England, E.			F England, N.W.			G Ireland, N.			H Scotland, W.		
Hazel	43	38	+ 5	56	43	+13	61	52	+ 9	67	*54*	+13
Coltsfoot	71	60	+11	75	64	+11	83	71	+12	85	*76*	+ 9
Wood Anemone	95	88	+ 7	100	94	+ 6	102	87	+15	105	*100*	+ 5
Blackthorn	107	98	+ 9	116	104	+12	111	99	+12	116	*111*	+ 5
Garlic Hedge Mustard	118	111	+ 7	132	124	+ 8	...	*119*	...	133	*126*	+ 7
Horse-chestnut	129	125	+ 4	138	129	+ 9	137	129	+ 8	145	*141*	+ 4
Hawthorn	135	129	+ 6	149	136	+13	149	138	+11	140	*144*	− 4
White Ox Eye	152	145	+ 7	160	150	+10	155	153	+ 2	160	*159*	+ 1
Dog Rose	162	156	+ 6	170	160	+10	168	163	+ 5	165	*171*	− 6
Black Knapweed	186	178	+ 8	196	186	+10	204	181	+23	193	*188*	+ 5
Harebell	189	187	+ 2	191	184	+ 7	...	*194*	...	189	*201*	−12
Greater Bindweed	195	190	+ 5	207	190	+17	204	*196*	+ 8	199	*203*	− 4
Ivy	271	263	+ 8	291	281	+10	278	*274*	+ 4	279	*281*	− 2
Mean for the 13 Plants	143	136	+ 7	152	142	+10	150*	140*	+10*	152	*150*	+ 2

Plants.	I England, N.E.			J Scotland, E.			K Scotland, N.			British Isles.		
Hazel	70	*51*	+19	71	*53*	+18	58	*49*	+ 9	54	45	+ 9
Coltsfoot	85	*73*	+12	87	*75*	+12	83	*71*	+12	78	66	+12
Wood Anemone	106	*97*	+ 9	116	*99*	+17	108	*95*	+13	101	91	+10
Blackthorn	116	*108*	+ 8	126	*110*	+16	119	*106*	+13	112	101	+11
Garlic Hedge Mustard	130	*123*	+ 7	140	*125*	+15	...	*121*	...	125	*116*	+ 9
Horse-chestnut	143	*138*	+ 5	153	*140*	+13	144	*136*	+ 8	138	130	+ 8
Hawthorn	145	*141*	+ 4	158	*143*	+15	155	*139*	+16	144	135	+ 9
White Ox Eye	164	*156*	+ 8	174	*158*	+16	172	*154*	+18	158	150	+ 8
Dog Rose	174	*168*	+ 6	172	*170*	+ 2	165	*166*	− 1	166	161	+ 5
Black Knapweed	193	*185*	+ 8	201	*187*	+14	211	*183*	+28	191	180	+11
Harebell	194	*198*	− 4	195	*200*	− 5	197	*196*	+ 1	193	*192*	+ 1
Greater Bindweed	204	*200*	+ 4	204	*202*	+ 2	186	*198*	−12	198	*193*	+ 5
Ivy	297	*278*	+19	291	*280*	+11	295	*276*	+19	280	*272*	+ 8
Mean for the 13 Plants	155	*147*	+ 8	161	*149*	+12	158†	*147*†	+11†	149	141	+ 8

* For 11 Plants. † For 12 Plants.

\+ indicates the number of days later than the average date.
− ,, ,, ,, earlier ,, ,,
Av. ,, average date (1891-1900).
The dates in *italics* are approximate averages.

cabbage lettuce lived through the winter without protection of any kind. *Brunstead* (E)—26th. Frog spawn first seen. *Saintfield* (G)—11th. Frog spawn first seen. *Newmill* (J)—18th. Frog spawn first seen.

April.—*Liskeard* (A)—Chiffchaff first heard. 21st. Willow-wren first heard. *Altarnon* (A)—21st. Brimstone butterflies abundant. 26th. St. Mark's fly first seen. *St. Arvans* (A)—17th. Chiffchaff first heard. 19th. Willow wren first heard. *Glendalough* (B)—29th. All rhododendron blossoms destroyed by frost. *Bembridge* (C)—20th. Cut first asparagus, eight days later than last year. *Coneyhurst* (C)—22nd. Swift first seen. *Churt Vicarage* (C)—Bloom on blackthorn exceptionally abundant. 17th. Wryneck first heard. *Bagshot* (C)—26th. Peas slightly injured by frost. *Oxford* (D)—Flowers on elms extremely numerous. *Watford* (*The Platts*) (D)—22nd. Blackthorn flowering freely. *St. Albans* (D)—19th. Willow-wren and chiffchaff first heard. 20th. Wryneck first heard. *Ripley* (D)—20th. Chiffchaff first heard. *Tacolneston* (E)—19th. Wryneck first heard. *Palé* (F)—Wasps very plentiful. *Loughbrickland* (G)—28th. Corncrake first heard.

May.—*Marazion* (A)—9th. Swift first seen. *Mawnan* (A)—19th. Swift first seen. *Liskeard* (A)—2nd. Swift seen. *Bridgend* (A)—3rd. Corncrake first heard. *Gowerton* (A)—9th. Corncrake first heard. *St. Arvans* (A)—8th. Horse-chestnut leaves withered and brown from continued cold winds. *Killarney* (B)—26th. My medlar tree in flower, or later than in any of the five previous years. *Bembridge* (C)—Bloom on apples, pears, etc., singularly abundant. *Buckhorn Weston* (C)—Fruit blossom very abundant. *Coneyhurst* (C)—Blossoms on blackthorn, hawthorn, etc., most abundant. 21st. Blackthorn still in flower. *Churt Vicarage* (C)—Bloom on apples and pears very abundant. 4th. Swift first seen. 25th. First May-fly. *Chiddingfold* (C)—The oaks escaped the ravages of caterpillars, so destructive during the last five years. *Bagshot* (C)—The grass made but little growth. *Oxford* (D)—Scarcely any swallows or swifts seen till after the middle of the month. *Wealdstone* (D)—8th. Swift first seen. *St. Albans* (D)—6th. Swift first seen. 9th. House-martin first seen. *Leominster* (D)—Scarcely any caterpillars this year on copper beeches, oaks, etc. *Northampton* (D)—The frosts early in the month injured even barley and young beans. *Beeston* (D)—2nd. Splendid bloom on damsons. *Ripley* (D)—8th. Swift first seen. 9th. Corncrake first heard. *Tacolneston* (E)—Fruit-trees blooming profusely. An unusual number of blackbirds and thrushes. 5th. House-martin first seen. *Palé* (F)—Blossom unusually abundant on fruit-trees. *Ambleside* (F)—17th. Corncrake first heard. *Westport* (G)—6th. Swift first seen. *Jardington* (H)—7th. Corncrake first heard. *Helensburgh* (H)—Foliage of trees slow in development, but unusually perfect, owing to absence of greenfly and other pests. *Corbridge-on-Tyne* (I)—4th. Corncrake first heard. *Chirnside* (I)—5th. Swift first seen. *Newmill* (J)—4th. Corncrake first heard. 9th. Swift first seen. *Watten* (K)—24th. Corncrake first heard.

June.—*Bridgend* (A)—26th. Hay first cut. *St. Arvans* (A)—17th. Hawthorn very full of blossom. 18th. First hay cut. *Killarney* (B)—A plague of gooseberry caterpillars. *Churt Vicarage* (C)—Very few butterflies this year. *Churt* (C)—18th. Several clouded yellow butterflies seen. *Chiddingfold* (C)—Greenfly more numerous than usual on roses. *Bagshot* (C)—19th. Haymaking began. *Wealdstone* (D)—18th. Hay harvest began. *Harpenden* (D)—13th. First wheat ear out of sheaf, or four days later than its average date in the previous eight years. *Northampton* (D)—11th. Severe hailstorm. Gooseberries and young shoots of roses knocked off in large quantities. Although hailstones unusually large, comparatively little damage was altogether done. *Bocking* (E)—Fine display of blossom on most kinds of fruit and other flowering trees. *Market Weston* (E)—There are reduced numbers of most migratory

TABLE V.—DATE (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS, 1900.

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
A											
Tresco	...	...	110	...	...	350	...	...	...	...	...
Marazion	14	105	113	...	...	282	113	...	83	150	188
Mawnan	1	115	113	...	...	281	...	98	109	135	179
Liskeard	1	107	110		144		70	...	108	127	111
Altarnon	21	102	111	...	115	293	69	100	109	108	111
Westward Ho	10	*137*	*142*	...	*166*	269	70	...	98	...	195
Sidcot	...	101	108	...	129	285	56	111	...	116	...
Clifton	...	108	115	112	...	...	...	...	112	...	...
Penarth	...	...	...	...	...	...	111	110	113	140	182
Bridgend	26	119	112	...	...	280	69	128	108	130	...
Gowerton	...	105	...	...	...	...	...	94	...	...	...
Castleton	25	106	112	...	143	296	54	98	110	125	178
Bassaleg	23	106	106	125	127	284	54	69	95	108	129
St. Arvans	21	117	120	...	131	280	...	93	110	145	...
St. Davids	...	114	106	...	...	...	54	...	124	135	...
Aberystwith	8	108	117	...	...	...	23	111	111	131	170
B											
Skibbereen	11	113	114	...	...	312	62	113	110	114	171
Cork	3	...	...	...	...	...	...	...	...	...	...
Killarney	12	114	*128*	...	...	272	...	84	114	137	...
Cappagh	...	115	114	...	138	...	...	...	...	...	...
Ferns	2	105	110	...	...	276	71	108	109	122	136
Glendalough	...	118	113	...	118	...	56	128	110	136	...
Geashill	...	103	120	...	...	278	55	113	109	128	189
C											
Bembridge	16	102	112	109	...	309	56	96	111	147	168
Blandford	...	106	106	109	114	...	56	111	57	125	170
Buckhorn Weston	2	104	110	113	128	284	...	112	108	118	177
Havant	15	105	105	110	...	302	13	110	106	146	179
Botley	20	106	110	109	126	292	52	104	108	131	...
Breamore	16	...	...	...	...	...	48	...	...	...	...
Muntham	17	107	98	109	130	289	70	119	95	121	...
Dover	...	...	...	...	...	330	...	...	...	...	...
Chiddingfold	22	107	104	109	...	280	22	91	*136*	136	164
Winterfold	33	110	104	108	...	300	62	109	...	...	...
Coneyhurst	*55*	111	107	109	135	...	57	110	69	116	...
Churt Vicarage	22	105	105	109	132	286	56	112	109	134	178
Churt	14	102	103	108	130	301	25	49	99	125	...
Oxshott	28	110	109	121	...	282	...	...	...	...	...
Bagshott	...	117	110	121	...	281	...	110	...	...	...
East Molesey	...	...	111	111	...	...	93	112	...	...	...
Weston Green	9	106	111	111	141	295	55	110	108	...	...
Marlborough	25	107	106	122	133	...	...	...	108	128	173
D											
Oxford	...	110	112	...	...	...	...	...	...	...	...
Beckford	50	106	108	110	135	281	17	96	...	148	167
Wealdstone	...	114	...	118	...	276	...	...	...	...	..
Chesham	...	109	111	110	...	282	...	110	96	125	...
Watford (The Platts)	...	...	112	115	...	...	...	119	116	...	...

TABLE V.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1900—*Continued.*

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
Watford (Weetwood)	...	111	111	112	...	...	64	116	108	...	...
St. Albans	5	106	108	109	...	...	...	...	...	...	...
Berkhamsted	20	102	109	110	127	282	54	112	103	146	104
Harpenden	54	110	111	111	...	...	...	...	107	...	...
Ross	15	108	111	125	137	294	69	66	125	...	...
Leominster	31	107	111	110	121	293	70	112	112	140	...
Farnborough	8	107	110	*133*	135	282	50	...	109	136	161
Ullenhall	42	104	111	107	123	...	45	86	112	*94*	126
Thornhaugh	59	107	109	110	124	284	73	109	119	123	...
Churchstoke	53	108	113	...	...	278	...	...	127	135	177
Thurcaston	...	110	110	...	...	...	...	109	*137*	146	...
Beeston	26	107	112	...	129	...	89	108	107	...	...
Hodsock	24	110	115	115	130	300	51	111	121	153	...
Macclesfield	16	114	111	...	...	277	...	...	*144*	...	...
Belton	26	109	113	116	145	...	50	110	111	...	...
Sheffield	21	114	120	...	...	270	...	*153*	...	...	...
Horbury	7	110	117	...	148	293	...	142	111	...	...
Ripley	58	109	112	...	140	...	56	127	128	...	...
E											
Broxbourne	8	...	110	113	126	302	44	111	111	...	...
Hatfield	23	118	113	109	128	...	...	...	...	...	...
Sawbridgeworth	23	109	109	112	134	297	55	101	112	127	179
Hitchin	20	98	112	108	...	283	...	108	...	125	...
Odsey (Ashwell)	...	107	...	116	126	282	...	...	...	...	...
Bocking	...	112	111	119	...	...	108	127	...	...	...
Lexden	22	108	108	109	136	...	49	94	112	137	180
Sproughton	12	111	114	121	132	302	53	55	111	123	...
Market Weston	24	107	114	109	127	285	54	91	116	119	181
Tacolneston	...	111	112	114	...	...	...	...	110	122	...
Brundall	...	...	108	109	...	...	...	...	...	...	...
Brunstead	19	108	109	...	141	286	66	71	109	122	186
Hevingham	53	108	113	117	...	...	...	...	...	...	...
Clenchwarton	23	114	111	...	...	295	56	83	111	130	...
Peterborough	23	108	108	121	128	289	50	111	108	146	...
F											
Palé	55	107	112	...	133	260	54	110	122	154	192
Alderley Edge	...	109	117	...	130	...	...	...	...	...	...
Ambleside	24	123	120	...	...	271	70	137	109	...	...
Cronkbourne	25	118	123	...	...	279	33	111	103	...	179
Orry's Dale	12	113	111	...	...	...	63	112	110	...	...
Sulby	18	110	108	...	...	292	100	100	109	...	148
G											
Ardgillan	25	107	111	...	...	277	...	70	119	144	148
Edgeworthstown	...	105	112	...	...	278	63	...	120	134	120
Westport	...	109	110	...	...	...	...	...	...	...	...
Loughbrickland	56	108	118	...	...	277	70	...	126	139	...
Saintfield	30	116	117	...	145	...	70	...	116	136	...
Antrim	24	109	118	...	140	...	111	111	109	158	...
Altnafoyle	...	112	126	...	...	...	...	152	126	152	162
Ramelton	24	105	115	...	...	274	...	*165*	129	145	...

TABLE V.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1900—*Continued.*

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
H											
New Galloway	55	110	109	...	...	...	61	...	114	...	...
Jardington	22	110	128	...	...	...	...	135	125	...	192
Helensburgh	13	125	119	...	...	...	100	152	128	...	...
Duror	53	117	117	...	...	283	53	152	130	...	...
I											
Thirsk	26	112	116	...	141	298	57	114	105	...	...
East Layton	24	120	125	...	140	...	...	118	134	154	...
Willington	55	117	117	...	...	274	56	118	129	154	...
Corbridge-on-Tyne	55	123	126	...	...	274	69	...	...	...	...
Blyth	26	114	118	...	...	...	49	49	100	...	...
Lilliesleaf	56	...	...	...	...	294	66	*256*	...	...	...
Chirnside	55	116	120	...	152	277	94	120	*171*	*181*	191
J											
Kirriemuir	...	123	...	...	...	271	61	...	...	...	...
Aberdeen	26	132	*155*	...	...	250	116	...	144	...	...
Newmill	...	116	126	...	...	279	70	123	128	...	168
K											
Invermoidart	25	...	122	...	...	...	...	...	110	...	...
Roshven	10	124	123	...	...	...	...	149	126	...	...
Beauly	*79*	137	140	...	...	250	61	140	146	157	...
Dingwall	26	126	138	...	...	260	58	132	134	...	...
Inverbroom											
Watten	...	...	*152*	...	...	...	90	...	145	...	110
Mean Dates for the British Isles in 1900	25 Jan. 25th.	111 Apl. 21st	113 Apl. 23d	113 Apl. 23d	133 May 13th	285 Oct. 12th	63 Mar. 4th	108 Apl. 18th	113 Apl. 23rd	134 May 14th	164 June 13th
Mean Dates for 1891-1900	Jan. 28th.	Apl. 17th	Apl. 21st	Apl. 21st	May 13th	Oct. 13th	Feb. 26th	Apl. 9th	Apl. 15th	May 7th	June 9th

The dates in *italics* have not been taken into consideration when calculating the means for the British Isles.

birds this summer. *Palé* (F)—Hawthorn very full of bloom. ***Ambleside*** (F)—27th. Haymaking began. *Cronkbourne* (F)—Fruit-tree blossom unusually abundant. *Ramelton* (G)—Apple and pear blossom unusually abundant. *Jardington* (H)—For some years there has not been a June so favourable to farm crops generally. *Thirsk* (I)—3rd. Early peas in flower. *Willington* (I)—2nd. Ash trees only just breaking into leaf. *Chirnside* (I)—2nd. Hawthorn

Description of Crop.	England.						Scotland.			Ireland.	British Isles.
	A S.W.	C S.	D Mid.	E E.	F N.W.	I N.E.	H W.	J E.	K N.	B and G S. and N.	
Wheat	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	Av.	Av.	U. Av.	Av.	Av.	U. Av.
Barley	Av.	U. Av.	U. Av.	U. Av.	Av.	Av.	Av.	O. Av.	Av.	Av.	U. Av.
Oats	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	O. Av.	O. Av.	O. Av.	O. Av.	U. Av.
Corn Harvest began, average Date	218 (Aug. 6)	213 (Aug. 1)	218 (Aug. 6)	216 (Aug. 4)	224 (Aug. 12)	233 (Aug. 21)	235 (Aug. 23)	240 (Aug. 28)	249 (Sept. 6)	227 (Aug. 15)	227 (Aug. 15)
Beans	Av.	U. Av.	Av.	U. Av.	Av.	O. Av.	Av.	O. Av.	...	Av.	Av.
Peas	Av.	Av.	U. Av.	Av.	Av.	Av.	...	Av.	...	U. Av.	Av.
Potatoes	Av.	Av.	U. Av.	U. Av.	Av.	Av.	O. Av.	O. Av.	O. Av.	U. Av.	Av.
Turnips	U. Av.	U. Av.	Av.	U. Av.	U. Av.	Av.	O. Av.	Av.	Av.	O. Av.	U. Av.
Mangolds	O. Av.	O. Av.	O. Av.	Av.	O. Av.	O. Av.	O. Av.	Av.	...	O. Av.	O. Av.
Hay (Permanent Pastures)	O. Av.	U. Av.	U. Av.	U. Av.	Av.	Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Hay (Clover, etc.)	O. Av.	U. Av.	U. Av.	U. Av.	Av.	Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.

The variations from the average for the above crops have been obtained from the returns which appeared in the *Agricultural Gazette*, July 30–September 3, 1900.

TABLE VII.—ESTIMATED YIELD OF FRUIT CROPS IN 1900.

Description of Crop.	England.						Scotland.	Ireland.	British Isles.
	A S.W.	C S.	D Mid.	E E.	F N.W.	I N.E.	H, J, and K W. E. and N.	B and G S. and N.	
Apples	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	Av.	O. Av.	O. Av.
Pears	Av.	O. Av.	U. Av.	Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.
Plums	O. Av.	O. Av.	O. Av.	O. Av.	Av.	O. Av.	O. Av.	O. Av.	O. Av.
Raspberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Currants	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Gooseberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Strawberries	O. Av.	Av.	U. Av.	Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.

Symbols:—O. = Over. U. = Under. Av. = Average. This Table has been compiled from returns which appeared in the *Gardeners' Chronicle*, Aug. 4, 1900.

TABLE VIII.—Variations from the Average in Mean Temperature, Rainfall, and Sunshine, 1899-1900.

Winter 1899-1900.

Temperature.

Months.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	°	°	°	°	°	°	°	°	°	°	°
December . .	- 1·8	+ 0·3	- 2·0	- 3·8	- 2·8	- 3·5	0·0	- 2·0	- 3·3	- 3·3	- 0·5
January . .	+ 1·6	0·0	+ 1·4	+ 1·0	+ 1·2	+ 1·0	+ 0·4	+ 0·6	+ 1·0	+ 0·8	+ 0·8
February . .	- 2·0	- 5·3	- 1·0	- 2·0	- 1·3	- 2·8	- 4·3	- 4·0	- 3·5	- 5·0	- 4·8
Winter . .	- 0·7	- 1·7	- 0·5	- 1·6	- 1·0	- 1·8	- 1·3	- 1·8	- 1·9	- 2·5	- 1·5
						Rain.					
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
December . .	0·0	+ 3·8	- 0·7	- 0·3	- 0·8	- 0·1	+ 2·1	- 0·5	+ 0·7	+ 0·9	- 0·9
January . .	+ 1·3	+ 0·1	+ 0·9	+ 0·9	+ 1·2	+ 1·0	+ 0·6	+ 0·5	+ 0·5	+ 0·7	+ 1·2
February . .	+ 2·6	+ 1·1	+ 2·3	+ 2·4	+ 1·7	+ 1·6	+ 0·6	0·0	+ 2·4	+ 0·7	- 1·8
Winter . .	+ 3·9	+ 5·0	+ 2·5	+ 3·0	+ 2·1	+ 2·5	+ 3·3	0·0	+ 3·6	+ 2·3	- 1·5
						Sunshine.					
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
December . .	- 9	- 16	- 6	- 7	- 9	- 3	- 16	- 11	- 13	- 14	+ 1
January . .	+ 4	+ 17	- 6	- 7	- 9	0	+ 29	+ 7	+ 3	+ 1	+ 5
February . .	+ 1	+ 16	- 1	+ 2	- 3	+ 5	+ 14	+ 14	- 10	+ 2	+ 16
Winter . .	- 4	+ 17	- 13	- 12	- 21	+ 2	+ 27	+ 10	- 20	- 11	+ 22
						Spring 1900. *Temperature.*					
	°	°	°	°	°	°	°	°	°	°	°
March . .	- 3·5	- 4·0	- 2·8	- 3·5	- 3·5	- 3·3	- 3·0	- 2·8	- 2·5	- 3·0	- 2·0
April . .	+ 0·5	+ 1·5	+ 0·3	+ 0·8	+ 0·3	+ 0·5	+ 0·8	+ 0·5	+ 1·5	+ 1·0	+ 0·8
May . .	- 1·4	0·0	- 1·0	- 1·6	- 0·6	- 1·2	- 0·2	0·0	+ 0·2	- 0·6	- 0·6
Spring . .	- 1·5	- 0·8	- 1·2	- 1·4	- 1·3	- 1·3	- 0·8	- 0·8	- 0·3	- 0·9	- 0·6
						Rain.					
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
March . .	- 0·9	- 1·3	- 0·6	- 0·9	- 0·7	- 1·4	- 1·3	- 2·6	- 0·6	- 0·2	- 1·9
April . .	- 0·6	- 0·2	- 0·8	- 0·7	- 0·5	+ 0·3	+ 0·5	+ 0·7	- 0·6	0·0	+ 1·8
May . .	+ 0·3	+ 0·1	- 0·4	- 0·3	- 0·2	- 0·5	+ 0·3	+ 1·1	- 1·0	- 0·6	+ 0·1
Spring . .	- 1·2	- 1·4	- 1·8	- 1·9	- 1·4	- 1·6	- 0·5	- 0·8	- 2·2	- 0·8	0·0
						Sunshine.					
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
March . .	- 21	- 23	- 23	- 15	- 14	+ 8	- 12	- 2	- 24	- 16	+ 9
April . .	+ 11	- 19	+ 25	+ 32	+ 36	+ 26	+ 2	+ 3	+ 16	+ 9	- 4
May . .	+ 10	+ 6	- 35	- 39	- 37	+ 7	0	+ 1	- 60	- 42	+ 2
Spring . .	0	- 36	- 33	- 22	- 15	+ 41	- 10	+ 2	- 68	- 49	+ 7

+ indicates above the average, - below it.

TABLE VIII.—VARIATIONS FROM THE AVERAGE—*Continued.*

SUMMER 1900.

Temperature.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	°	°	°	°	°	°	°	°	°	°	°
June . .	+0·3	0·0	+0·3	+1·3	+2·0	+1·3	+1·3	+1·5	+1·0	0·0	+1·5
July . .	+2·5	+2·3	+4·0	+4·0	+4·3	+2·8	+1·8	+2·0	+3·0	+1·8	+1·5
August . .	0·0	0·0	+0·2	+0·6	+0·4	−0·6	+0·2	−0·4	0·0	−1·0	+0·2
Summer . .	+0·9	+0·8	+1·5	+2·0	+2·2	+1·2	+1·1	+1·0	+1·3	+0·3	+1·1
Rain.											
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
June . .	+1·7	+2·2	+1·0	+0·2	+0·2	+0·6	+1·7	+1·3	+1·0	+0·7	0·0
July . .	−2·0	−0·2	−1·5	−1·0	−1·2	−1·3	−0·8	−0·4	−0·7	+0·5	+0·2
August . .	+0·3	+1·5	−0·1	+1·0	+0·9	+2·3	+0·1	+2·0	+2·2	+0·6	−0·5
Summer . .	0·0	+3·5	−0·6	+0·2	−0·1	+1·6	+1·0	+2·9	+2·5	+1·8	−0·3
Sunshine.											
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
June . .	−51	−36	+ 8	− 3	− 8	−11	−11	−22	−25	−40	−23
July . .	+44	+ 6	+80	+74	+82	+20	+13	−23	+47	− 7	−20
August . .	+46	+31	+25	+ 6	+ 4	+18	+ 9	−17	−17	−16	+44
Summer . .	+39	+ 1	+113	+77	+78	+27	+11	−62	+ 5	−63	+ 1
AUTUMN 1900. *Temperature.*											
	°	°	°	°	°	°	°	°	°	°	°
September .	+1·0	+1·3	+1·3	+1·0	+1·8	+1·3	+1·3	+0·8	+1·3	+0·5	+1·0
October . .	+2·2	+1·4	+2·0	+1·8	+2·0	+1·2	+0·4	0·0	+1·0	−0·4	0·0
November .	+0·8	−1·0	+1·8	+1·5	+1·8	+1·0	−0·5	+0·5	+1·8	+0·3	+0·3
Autumn . .	+1·3	+0·6	+1·7	+1·4	+1·9	+1·2	+0·4	+0·4	+1·4	+0·1	+0·4
Rain.											
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
September .	−2·3	−1·6	−1·9	−2·0	−1·8	−1·8	−0·8	+0·2	−1·7	−0·5	+0·8
October . .	0·0	+2·0	−1·3	0·0	−0·8	+1·4	+1·3	+1·9	+1·4	+0·9	+1·2
November .	+0·5	+2·6	+0·1	−0·1	−0·6	−0·2	+1·6	−0·1	−0·2	+1·2	−0·7
Autumn . .	−1·8	+3·0	−3·1	−2·1	−3·2	−0·6	+2·1	+2·0	−0·5	+1·6	+1·3
Sunshine.											
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
September .	+41	+42	+53	+27	+15	+48	+30	+16	+24	+17	+ 6
October . .	+ 5	− 9	+ 3	+ 9	+15	− 9	− 9	− 9	− 2	− 4	− 2
November .	+14	− 5	− 9	− 4	− 7	+ 4	− 7	+ 1	−14	−16	+ 7
Autumn . .	+60	+28	+47	+32	+23	+43	+14	+ 8	+ 8	− 3	+11

The above Table has been compiled from the variations from the mean given in the *Weekly Weather Reports* issued by the Meteorological Office.

flowering sparsely. *Aberdeen* (J)—Flowering shrubs and fruit-trees very rich in blossom.

JULY.—*Mawnan* (A)—13th. Hay harvest virtually over. *Clifton* (A)—11th. The second brood of the small white butterfly was noticed, or somewhat earlier than the average date. The clouded yellow butterfly rather plentiful. *Coneyhurst* (C)—Cuckoos not so plentiful as usual; last heard on 6th. *Churt* (C)—Very few wasps this year. *Bagshot* (C)—Very little trouble with the hay after the 4th. 3rd. Cuckoo last heard. *Wealdstone* (D)—30th. First wheat cut. *Northampton* (D)—20th. Severe hailstorm. *Hodsock* (D)—30th. Corn harvest began. *Horbury* (D)—Swallows and martins very scarce this year. The humming-bird hawkmoth more numerous than I ever remember. *Market Weston* (E)—16th. Sudden and violent squall from west, with thunder and hail. Potato plants riddled as if by shot; lettuces, rhubarb, peas, etc., damaged. *Clenchwarton* (E)—30th. Harvest began. *Palé* (F)—A great many humming-bird hawkmoths. *Jardington* (H)—Exceptional growth of grass; pasture fields in many cases like hay fields. *Willington* (I)—Humming-bird hawkmoth frequently seen. *Newmill* (J)—Very few wasps.

AUGUST.—*Marazion* (A)—Clouded yellow butterfly abundant this summer. 7th. Swift last seen. *Mawnan* (A)—Butterflies made their appearance very late this summer. One wondered when they were coming. *Liskeard* (A)—30th. Swift last seen. *Altarnon* (A)—6th. Destructive gale. Trees blown down, and foliage much injured and browned generally. *St. Arvans* (A)—1st. First corn cut. 3rd. Heavy gale; orchards strewn with apples. 15th. Wasps numerous. *Aberystwith* (A)—3rd. Great damage done to gardens by strong north-westerly gale. *Killarney* (B)—Wasps numerous. *Bembridge* (C)—3rd. Heavy gale. *Buckhorn Weston* (C)—Clouded yellow butterflies very numerous; also larvæ of all the hawkmoths. *Coneyhurst* (C)—31st. Great quantities of acorns. *Churt Vicarage* (C)—The largest apple crop for years as regards quantity, but fruit very small. *Bagshot* (C)—Wasps numerous. Many apples blown down by the gales of 3rd and 6th. *Beckford* (D)—2nd. Wheat harvest began. *Watford* (*The Platts*) (D)—Wild flowers very scarce. *Leominster* (D)—The worst year I ever remember for garden pests—aphides of all kinds, red spider, pear midge, fungus on tulips, violets, etc., etc. *Farnborough* (D)—Earwigs very destructive to dahlias. Small white butterflies comparatively scarce. Although limes and other trees have flowered profusely, yet bees have made little honey. Humming-bird hawkmoths abundant. *Hodsock* (D)—The grass became wonderfully green. *Hatfield* (E)—Wasps very numerous this season. *Market Weston* (E)—Very few humming-bird hawkmoths. But little honey made. Beechmast unusually abundant; also sloes. *Tacolneston* (E)—The common kinds of butterflies unusually numerous. *Palé* (F)—Wasps numerous. Wild fruits very abundant. *Cronkbourne* (F)—8th. Harvest began. *Orry's Dale* (F)—Wasps very numerous. *Antrim* (G)—14th. Swift last seen. *Jardington* (H)—9th. First corn cut. *Chirnside* (I)—30th. Last Swift. *Kirriemuir* (J)—Quite a plague of wasps. *Newmill* (J)—Butterflies numerous. 15th. Swift last seen.

SEPTEMBER.—*Mawnan* (A)—3rd. The foliage of many trees quite brown and withered through gales of last month. *Tiverton* (A)—25th. Leaves of horse-chestnut are dropping before they have coloured, owing to drought. *Aberystwith* (A)—Humming-bird hawkmoth unusually numerous. *Geashill* (B)—Potatoes much diseased. *Churt* (C)—5th. Scarlet runner beans cut down by frost. *Marlborough* (C)—The seed of the common elm exceptionally abundant. *Watford* (*The Platts*) (D)—Very few flies and scarcely any wasps. *Thornhaugh* (D)—Although this is a barley country, yet continued drought has spoilt the crop here.—In some cases the straw was only a foot high. *Hodsock* (D)—Hardly ever so few roses out during August and early part of this month.

Market Weston (E)—Potatoes badly diseased ; half the crop tainted or already rotten. *Clenchwarton* (E)—Berries of all kinds unusually abundant. *Palé* (F)—Wasps very numerous. Clouded yellow butterfly and humming-bird hawk-moth also in unusual numbers. Wild fruits abundant. *Orry's Dale* (F)—Very few holly berries or haws. *Sulby* (F)—Clouded yellow butterfly numerous ; also red admiral butterflies. *Antrim* (G)—4th. Flycatcher last seen. *Willington* (I)—Wasps fairly plentiful. Nuts and acorns scarce.

OCTOBER.—*Altarnon* (A)—1st. Blackberries and mushrooms late but plentiful. 20th. Dahlias cut by frost. *Sidcot* (A)—Blackberries, haws, acorns, and all wild fruits very abundant, but scarcely any mushrooms. *St. Arvans* (A)—21st. An extraordinary amount of beechmast; acorns and yew berries also abundant. *Aberystwith* (A)—21st. Dahlias cut down by frost. *Bembridge* (C)—Great plague of daddy-longlegs. *Churt* (C)—The finest and heaviest crop of swedes seen here for many years. *Chiddingfold* (C)—Garden almost as gay as in summer. *Bagshot* (C)—Numerous caterpillars on cabbages. *Hodsock* (D)—Garden unusually gay with flowers throughout the month. *Clenchwarton* (E)—Late autumn roses very abundant. *Ambleside* (F)—Yew and holly berries very plentiful. *Cronkbourne* (F)—Mushrooms very scarce. *Ramelton* (G)—A second crop of flowers on the rhododendrons. *Willington* (F)—4th. Dahlias killed by frost.

NOVEMBER.—*Altarnon* (A)—30th. Elms almost in full leaf still. *Sidcot* (A)—18th. Dahlias killed by frost. *Geashill* (B)—18th. Dahlias killed by frost. *Botley* (C)—Berries of all kinds abundant. 25th. Up to this date elms half covered with leaves. 30th. Leaves still thick on many oaks. *Churt Vicarage* (C)—11th. Dahlias killed by frost, the latest date since 1884. *Chiddingfold* (C)—Oaks still heavy with leaf, though brown, up to end of month. *Bagshot* (C)—11th. Dahlias killed by frost. Acorns and hollyberries abundant. 30th. The oaks still hold half their leaves. *Watford* (*The Platts*) (D)—11th. Dahlias killed by frost. *Horbury* (D)—A great number of wild plants in full bloom all through November. *Berkhamsted* (D)—11th. Dahlias killed by frost. *Tacolneston* (E)—Many stray blossoms out of season of dog rose, sweetbriar, dogwood, wild strawberry, etc. 11th. Dahlias killed by frost. 20th. Fieldfares first seen. *Ambleside* (F)—1st. Forty different wild flowers found in a walk of two hours. 30th. Many roses still blooming. *Cronkbourne* (F)—22nd. Dahlias killed by frost. 30th. Cut a bunch of good roses.

DISCUSSION.

The President (Mr. W. H. DINES) remarked that the Fellows were much indebted to Mr. Mawley, who year after year presented his valuable and interesting Report. They were all glad to see it, but few realised the amount of labour it involved.

Capt. A. CARPENTER asked if Mr. Mawley could account for the fact that the furze and hazel bloomed later in the north-west of England than in the east. He was under the impression that the eastern counties were colder than the north-western.

Mr. F. C. BAYARD said that he had listened for many years to Mr. Mawley's Reports, and he thought that the present one was even more interesting than those of previous years. He was under the impression that the season last year was earlier than usual, and was surprised to hear of its lateness. Vegetation was certainly both early and good in his own district to the south of Croydon. He believed that by aggregating the observations from different parts of the districts some of the details had been masked. As they were now at the commencement of a new decade, he hoped that Mr. Mawley would be able to

see his way to amplify some of the facts, and not to give the mean for each district as a whole. Wasps were said to be 9 days late, but he himself had noticed one in his own garden early in February.

Mr. W. B. TRIPP thought that the wasp Mr. Bayard had seen must have been a queen wasp, which had been hibernating through the winter. He hoped Mr. Bayard had destroyed the insect.

Mr. T. P. NEWMAN inquired whether it was usual to note date of first appearance of the bloom, or when the plant was in full flower. On Christmas day he had noticed that *Pyrus japonica* was on the point of appearing, but at the present time (February 20) it was still in the same state. He had also noticed as many as 53 varieties of plants in flower on Christmas day, including roses and other summer flowers; which was a far greater number than he had ever observed before at that time of the year. He had cut a bowl of roses, both teas and hybrids.

Mr. C. HARDING said that with regard to the diagram it had struck him that the first year of the series was very similar to the one under review. Both were backward seasons, but in the middle of the series much earlier dates were shown. The average flowering dates for the 13 plants for the ten years was of great value, and he hoped that Mr. Mawley would not have to curtail it at all. The Fellows were indebted to Mr. Mawley for the steady perseverance with which he worked at these Reports, and he was to be congratulated on the very able way in which they were presented.

Mr. J. E. CLARK remarked that, judging by the flowers at Christmas-time around Street, near Glastonbury, owing to the dry autumns, the flowering plants in the last three winters had had but a very poor start. The total number of flowers was more than the average, but the true spring ones were less. This year the primrose was the only prominent one out of a total of 40 wild plants. Of garden flowers, out of 107 kinds observed, very few spring bulbs were to be found, neither the snowdrop, aconite, nor ordinary crocus being present.

Mr. E. MAWLEY, in reply, said that the favourable reception his Report had met with was very encouraging, and more particularly so, as it was the tenth Report of the present series, the first having appeared in 1891. Consequently, sufficient time had elapsed for the merits of the system he had in that year adopted to be fairly tested. With regard to Capt. Carpenter's inquiry, the eastern district of England was certainly warmer and therefore more forward than the north-western; and judging from the earlier dates at which plants flowered in the former district it must, he thought, be also regarded as warmer than the midlands. He could not understand why Mr. Bayard should have considered the early months of last year unusually warm. The fact was that after January the spells of unseasonably warm weather lasted such a short time that the ground remained almost constantly below its average temperature until after the third week in April. He was afraid that the time at his disposal for these Reports would not allow him to give in future more detailed results than at present, but if these were required for a single locality he would be able to supply the necessary data from observations taken during the last fifteen years in his own garden at Berkhamsted. As to the method of observation, observers were required to note each year the date on which the first flower opened upon specially selected trees, etc. More trustworthy results might perhaps be obtained by entering instead the average dates for any half a dozen different hazels, blackthorns, etc., in each district, but he doubted very much whether he could obtain sufficient observers to take the increased number of observations that would then have to be made.

A REVIEW OF PAST SEVERE WINTERS IN ENGLAND, WITH DEDUCTIONS THEREFROM.

By ALBERT E. WATSON, B.A., F.R.Met.Soc.

[Read February 20, 1901.]

About 9 years ago, in a letter to *The Times*, I pointed out, as an interesting and remarkable fact, that during the last 40 years the winter from 0 to 1 in each decade has been distinguished by its great severity. Curious to see how far this would hold good, I searched past records and published the results in a local newspaper, and then let the matter drop; but recently, since another decade has rolled away, and we are again face to face with another 0 to 1 winter, I have examined the subject more thoroughly, and the results obtained are so peculiar and significant that they seem worthy of more than a local circulation. I will first, therefore, examine the severe winters of the last 300 years, make notes upon each in proof of its severity, and afterwards consider the results of these investigations, and the conclusions to which they point. The authority for the note is appended:—

1890-1.—One of the coldest and most severe winters on record. Frost commenced on November 25, and continued almost uninterruptedly till January 22.

1880-1.—Great and disastrous snowstorm on January 18, preceded and followed by very severe frost. Rivers coated with ice many inches thick.

1879-80.—Very severe winter. Mean temperature of December down to the freezing point.

1878-9.—Severe winter (Brumham). From November to April inclusive, the lowest temperature for 30 years.

1870-1.—Coldest November and December on record (Symons). Temperature down to 3° on December 25, and 5° on 31 (Whistlecraft).

1860-1.—The Christmas of 1860 is supposed to have been the severest ever experienced in Britain (Chambers). Severe winter; January very cold (Baker).

1849-50.—A cold and winterly Christmas, and January was severely cold to the end (Brumham).

1840-1.—Excessively severe winter (Brumham). December very severe; February severe frost and piercing gales (Almanack). January severe weather and much snow (Easton). Great snow and frost in January and February; on January 9, thermometer 4° (Whistlecraft).

1830-1.—Bitterly cold and sharp December, and January still colder.

1829-30.—Excessively severe winter (Brumham). January 19, heavy fall of snow; frost very severe; Salisbury coach 17 hours coming from Andover (Dowding). February 7, end of frost (Whistlecraft).

1819-20.—Excessively severe winter (Brumham). January and February extremely cold, with much snow (Almanack). Very severe winter, with great snows; January 15, thermometer 3° below zero (Whistlecraft).

1810-1.—A cold winter. Thames so much frozen that people could walk upon it (Thornbury). But not severe or long enough to include in this list (A. E. W.).

1799-1800.—Excessively severe winter, with severe frost at Christmas (Brumham). Severe frost and deep snow in February (Hone).

1798-9.—Very long and harsh winter. Bitter December. Severe frosts with much snow during January, February, and March (Kew Records).

1788-9.—Excessively severe winter; a very cold December, mean temperature 29° (BRUMHAM). Thames frozen over, and fair held on it from Shadwell to Putney (THORNBURY). A great frost for 3 months, November to February (ALMANACK).

1779-80.—A frost continued for 84 days this winter (BOYLE).

1770-1.—Severe frost till last week in January. Snow covered the ground for 8 weeks. At the end of March the face of the earth was naked to a surprising degree; no signs of any grass; all provisions rising in price. Frost to April 20 (WHITE). Thames entirely frozen over at Fulham in January (BOYLE).

1759-60. } These winters were cold, but the scarcity of records makes it
1750-1. } impossible to say how cold they were. Hence I omit them.

1740-1.—From September 15 to February 1 all frost or rain (WALFORD).

1739-40.—Severity of frost beyond precedent; several vessels were sunk by the ice, and a more dismal scene presented itself on the Thames than had ever been beheld by the oldest man living (THORNBURY). People dwelt on the Thames in booths for weeks (WHISTLECRAFT).

1730-1.—Great frost and snow in January; roads impassable; cold as great as in 1708 (DERHAM). February 9 and 10, river Thames frozen up (SHORT).

1728-9.—January 24, a hard frost began which lasted 9 weeks (ALMANACK). Severe winter (LOWE).

1718-9.—Great frost (LOWE). Severe winter (PENNY MAGAZINE). Very cold winter; much frost and snow (SHORT).

1710-1.—Most severe frost in January and February, freezing indoors. Ice 3 ins. thick on the coast (SHORT).

1708-9.—A hard frost which brought on a great scarcity of provisions (TOOKE). Thames frozen over; several people crossed on the ice (THORNBURY). Remarkably severe winter to a very late period of the spring (WHISTLECRAFT). Extremely cold. Frost so intense that rivers froze so as to bear loaded waggons. Cattle, sheep, and birds perished. Great quantities of snow fell (LOWE).

1698-9.—Here the severe winter fell a year earlier (A. E. W.).

1688-9.—January 7, a long frost and deep snow. Thames almost frozen over. It was now very hard frost, November 18, 1688 (EVELYN). Frost very severe in England; Thames frozen (LOWE).

1680-1.—Severe winter (PENNY MAGAZINE). Extraordinarily sharp and cold till March 27; frost and snow lying about, and not a leaf on the trees (EVELYN).

1678-9.—December 9 to February 9, with one remission (WALFORD).

1669-70.—Colder than for 5 or 6 years. Coldest date, December 24, after which a great snow; much colder than in 1665 and 1666 (Dr. BEAL). Hard frost at Christmas; frost most intense this winter (LOWE).

1659-60.—Severe frost, very cold winter; price of wheat doubled (LOWE).

1648-9.—Now was the Thames frozen over, and horrid tempests of wind (EVELYN). Great frost in January; Thames frozen over (LOWE).

1639-41. } No records of the winters of these dates now to be found (A. E. W.).
1629-31. }

1619-20.—There was a frost fair on the Thames (THORNBURY). Thirteen days snow in Scotland, where on Eskdale Moor out of 20,000 sheep only 45 were left alive (LOWE).

1609-10.—A most rigorous hard frost, from December to April; the Thames became a highway; birds and garden stuff killed (SHORT).

Hence we arrive at our first conclusion, an interesting one:—During the last 300 years, in each decade, one at least of the 3 winters ending with the numbers 8-9, 9-0, or 0-1, has been, with but one or two

proved exceptions, noted for its great severity. There does not seem to be any distinct rule as to which of these 3 winters in each decade will be the severe one; in one case, 1879–81, all are; in 5 other cases, 1829–31, 1739–41, 1728–31, 1708–11, and 1678–81, two are; but generally, only one. Sometimes the choice falls on the same one of these 3 years again and again, *e.g.* from 1688 to 1730, with one break, the winter from 8–9 was very severe 4 times over; this series was followed by the astounding frost of 1739–40. Towards the middle of the eighteenth century, the severe winter advances to the 9–0, and 0–1 years, for after the winter of 1798–9, the 8–9 year does not recur for 80 years, viz. till 1878–9. During the last 100 years, commencing with 1799, one of the two winters, 9–0 or 0–1, has been, with only one exception, and that but a partial one, remarkable for its great severity; and as we travel onward through the century, we find the figures 0–1, which had only occurred 5 times between 1650 and 1800, gradually becoming more and more established, for whereas in the first 6 decades of the nineteenth century they only occur twice, in the last 4 they occur every time, the winters of 1860–1, 1870–1, 1880–1, and 1890–1 all having been noted for their great severity. Query, by the end of the next century will there have been another advance, so that the figures 1–2 shall then mark the severe winter? Probably not, judging from past centuries. It must not of course be supposed that the winters hitherto mentioned are the only very severe ones on record since 1600; we shall therefore proceed now to examine another series in the same way:—

1894-5.—See below.

1885-6.—Very severe, January to March; bitterly cold and frosty February.

1874-5.—Bitterly cold all December and February. Mean temperature of December 6°, and of February 4°, below the average.

1864-5.—Five months' winter; very cold November to March; the latter month 5° below the average.

1854-5.—Excessively severe winter (Brumham). February extremely cold month, 10° below the average, most intense frost before the end of month (Baker).

1853-4.—Severe frosts and snow (Brumham). December 6° below average. Deep snow in January; roads impassable (Baker).

1844-5.—Severe frost January 27 to March 21. Coldest February for 50 years; probably no such March on record (Baker).

1835-6.—Excessively severe December (Brumham).

1825-6.—Excessively cold January, and cold November (Kew Temperatures).

[These last two winters are not reckoned in this paper, since only one month in each was excessively severe.—A. E. W.]

1815-6.—Very long and cold winter, lasting 6 months, November to April (Kew Temperatures).

1813-4.—Excessively severe winter (Brumham). The deepest snow for 40 years in January, succeeded by a frost unexampled in its duration or intensity, which lasted till March 20; a sheep roasted and complete fair on the Thames (Hughson).

1804-6.—No very severe winter at these dates (A. E. W.).

1794-5.—Excessively severe winter (Brumham). January coldest on record. Excessively cold and winterly till March 31 (Boyle).

1784-5.—The winter was most severe (Glaisher). Great frost 16 weeks

(ALMANACK). Frost lasted 115 days (BOYLE). Coldest March on record (BRUMHAM).

1783-4.—A very severe winter (BRUMHAM). Vast snow in December; all the furze and most of the ivy killed. Frost exceeded any since 1741 (WHITE). A frost continued for 89 days this winter (BOYLE).

1775-6.—Very cold winter (WHISTLECRAFT). Greatest fall of snow ever remembered (BOYLE). January 31, thermometer at zero, and Thames frozen (WHITE).

1773-4.—Severe frosts and great snows; ground frost-bound for nearly two months; a very long and harsh winter (GLAISHER).

1765-6.—Evidences of a cold winter; but data not very clear. Hence omitted (A. E. W.).

1753-4.—Very severe (WALFORD; ANDREW).

1745-6.—Great frost from February 1 to the middle of March; numbers of cattle killed and farmers ruined (STANDARD).

1733-5.—No severe winter here (A. E. W.).

1725-6.—Sharp frost and very much snow, with intense cold, in January (SHORT).

1715-6.—Thames frozen for three months, and a fair held on it; two oxen roasted; vast quantities of snow (THORNBURY). Severe frost November 24 to February 9 (ALMANACK).

1705-6.—A cold winter, but not cold enough for this list (A. E. W.).

1694-5.—Frost so intense that many forest trees and oaks were split by it (CHAMBERS). Thames frozen over. Most severe cold and snowy winter till end of March (EVELYN).

1684-5.—Frost lasted 91 days (BABERT). It proved so sharp weather and so long and cruel a frost that the Thames was frozen across. Such two winters (*i.e.* as this and the next mentioned—A. E. W.) I had never known (EVELYN).

1683-4.—Longest frost on record; ice on the Thames became 11 ins. thick (LOWE). January 24, the frost continuing more and more severe, the Thames was planted with booths in formal streets, all sorts of trades and shops full of goods, even to a printing-press, where the people had their names printed with the day and year. Coaches plied from Westminster to the Temple as in the streets, and there were horse and coach races, puppet plays, bull-baiting, etc. Fowls, fish, and birds perishing. Many parks of deer destroyed. London, by reason of the excessive coldness of the air hindering the ascent of the smoke, was so filled with the steam of the sea-coal that one could scarcely see or breathe (From EVELYN).

1673-4.—Severe frost nearly all February and March (SHORT). Thirteen days' drifting snow in Scotland (SOMERSET MAGAZINE). Eleven days' snow in England; people smothered (BAKER).

1664-5.—Excessive sharp frost and snow (EVELYN). A very violent frost froze up all things from the beginning of winter to the beginning of March (LOWE).

1655-6.—A cold winter, but not cold enough for this list. Hence omitted (A. E. W.).

1645-6.—December 8 to January 17, severe (WALFORD; SHORT).

1634-5.—Thames frozen over (THORNBURY). A severe frost and heavy snow in January (HATCHER).

1625-6.—A severe winter followed the infectious summer of 1625 (LOWE).

1614-5.—January 16, very heavy snow fell. It covered the earth 5 quarters deep upon the plain. Ten lesser snows in April. A foot of snow still upon the moors on May-day (*Youlgrave Register, Derbyshire.* BAKER). Eleven weeks' frost at York (WHITTOCK's *York*).

1604-6.—No records to be found (A. E. W.).

Hence we arrive at our second conclusion:—During the last 300 years one at least of the 3 winters ending in the numbers 3–4, 4–5, or 5–6, in each decade, has been, with very few proved exceptions, noted for its great severity. There seems no clear rule as to which of these 3 winters will be very severe; there is no instance of all of them being so in any one decade, as there was in the other series, but 2 of them have been so several times, as between 1683 and 85, 1773 and 76, 1783 and 85, 1813 and 1816, and 1853 and 55. The choice of the year seems more irregular than in the other series, the same numbers not occurring in more than 4 decades in succession; but during the last 7 decades the year 4–5 distinctly predominates, as it distinguishes a severe winter 5 out of 7 times.

Of course all the winters hitherto spoken of were not equally severe, but that they were all very severe is clearly proved by the appended notes; probably the very worst were the awful winters of 1739–40, and 1683–4, about which I have given fuller notes. Query, can the winter of 1890–1 be ranked with these two? Probably not, either in length or severity, though it was one of the worst in our generation.

We have now enumerated 58 very severe winters, all falling within the numbers specified, and this leads us on immediately to our third conclusion, which comes out with startling distinctness:—There are only 11 other winters on record in the last 300 years noted for great severity. These winters are those of 1846–7, 1837–8, 1822–3, 1796–7, 1767–8, 1762–3, 1697–8, 1696–7, 1687–8, 1657–8, and 1607–8, and curiously enough, 6 of these exceptions are in the numbers 7–8.

This list is the result of a thorough and careful search, and may be verified by any one who likes to go over the same ground again; there are perhaps half a dozen other winters mentioned which were severe for a short time, but no others that I can find equal to those mentioned or worthy to come into this list.

The records of temperature at Greenwich Observatory date back to 1771; I have copied out the monthly values of the whole series, and compared each with the average value of that month, and after examination, I find they confirm the notes above given down to that date in every instance, besides supplying a few other winters which I should not otherwise have obtained.

Sixty-nine severe winters have now been given; the following table shows the number corresponding to each of the years 0–1, 1–2, etc., in each century, and the total in the 300 years:—

Year.	19th Century.	18th Century.	17th Century.	Last three Centuries.
0–1	6	4	1	11
1–2	0	0	0	0
2–3	1	1	0	2
3–4	2	3	2	7
4–5	5	2	5	12
5–6	2	4	2	8
6–7	1	1	1	3
7–8	1	1	4	6
8–9	1	5	3	9
9–0	4	3	4	11
Total	23	24	22	69

From the first column it will be seen that all the severe winters of the present century except 3 fall within the specified dates, the years 9–0 and 0–1 accounting for 10 of them, and the year 4–5 for 5. The number 8–9 only gives 1 in this century, but there was not a single severe winter corresponding to the numbers 1–2 throughout the 300 years, only 2 corresponding to the numbers 2–3, and only 3 to the numbers 6–7! How striking these tables appear when one looks into them!

With regard to the severe winters of the present century, in addition to those included, there were 7 other winters that were distinctly cold, though not severe enough to be included in these tables, viz. those of 1810–1, 1812–3, 1825–6, 1835–6, 1841–2, 1859–60, and 1886–7. It will be seen that 4 of these also fall within the specified dates. Every cold winter in the nineteenth century has now been mentioned.

Now we arrive at our fourth conclusion:—Roughly speaking, the maximum severity of frost is attained twice in each decade, once in the middle, and once at the beginning or end, and the winters most liable to it occur in the years 4–5 or 5–6 in the middle, and 9–0 or 0–1 at the end. Therefore, I wrote 9 years ago, if these laws hold good in the future as they have in the past, the next two most severe winters will occur in the winters 1894–5, or 1895–6 on the one hand, and in 1899–1900 or 1900–1 on the other. Now, we all remember the extremely severe winter of 1894–5, 6 weeks' skating, one of the coldest Februarys on record, burst drains and water-pipes all over London. How extremely interesting it will be to see how the present winter, 1900–1, behaves itself when it comes to an end!

Another peculiar fact may be noted here, which, though in many cases difficult to ascertain, has yet sufficient evidence in its favour to warrant us in arriving at our fifth conclusion:—The severe winter in the middle of each decade is generally a late one, January to March (10 clear instances of this); the severe winter at the beginning or end of each decade is generally either an early one, November to January (6 clear instances), or else a very long one, November to March (several instances). The last 2 extreme winters are notable illustrations of this, for in 1890 the frost began in November 25, and lasted till January 22, and in 1894 it began on December 30, and lasted, with one break, till March 5.

Now, if these rules hold good since 1600, ought they not to hold good also in earlier centuries? If we can prove that they do so, they will surely be very greatly confirmed. Unfortunately, in early dates, records are scarce, and when found, it is not always possible, through the carelessness of observers, to decide which winter is meant; *e.g.* 1410 is mentioned as a severe winter, but it is impossible to say whether 1409–10, or 1410–11 is meant, and so with others. And though, at first sight, it appears as if the fact that the year then began in March ought to make matters easier, it is not so in reality, rather the reverse, as it frequently leads to greater difficulty.

It will be best for me to write down, first, all the severe winters on record, which must have fallen into the prescribed numbers; secondly, all those which could not have done so; and thirdly, all those which are doubtful, and may or may not have followed these rules; we shall then see clearly to what extent they confirm or weaken the above conclusions.

The books which I have studied for the purposes of this paper are the following:—Andrews' "*Famous Frosts and Frost-fairs*," Baker's "*Records of Seasons, etc.*," Lowe's "*Natural Phenomena*," Walford's "*Famines of the World*," Chambers' "*Book of Days*," and "*Encyclopedia*," Glaisher's "*Tables of Temperature*," Short's "*Chronological History*," a most valuable work in 2 volumes, and a manuscript diary belonging to a noted meteorologist, and dating back several hundred years. None of the books give complete lists, and in several of them mistakes can be detected, *e.g.*, Walford, whose list is perhaps as reliable as any, gives 1706–7 as a severe winter from January to April, but Short's *Chronological History* gives 1709–10 as a severe winter during the same months, and describes 1707 fully as a moderate winter, and Lowe, Baker, and Andrew confirm this, and so with other dates. But by exercising great care, and comparing one authority with another, and all of them together, over and over again, I think I may claim to have eliminated most mistakes, and to have obtained a list as reliable as it can be made with the materials available. Where several authorities agree as to a severe winter, I have not appended names; but where the record is to be found only in one or in two books, I have, for the sake of verification, prefixed the initial letter of the name of the author of those books, together with brief notes, when interesting.

The first list (winters within the prescribed numbers) is as follows:—

B. L., 1580-1, frost very intense in England; B. S., 1568-9, extremely sharp winter; 1564-5, football played on the Thames; 1543-4, severe winter, a famine; B. L., 1534-5, great frost, November to February; 1523-4, sore frost, so extreme that men died of cold, or lost fingers, toes, and nails; 1515-6, Thames frozen and used as a highway; 1505-6, Thames bore carriages throughout January; 1438-9; 1434-5, Thames frozen from November to February so as to bear heavy waggons, ale and wine sold in Scotland by the pound and melted at the fire; A., 1410; 1363-4, extreme sore frost December to March, ground lay untilled; 1338-9, such a vehement frost, beginning in December and lasting 12 weeks, that it destroyed almost all the seed sown; B., 1310-1; S. B., 1305-6, winter of extreme coldness, fish, birds, and cattle died, others so wasted as to be easily caught by hand; 1288-9, severe, cold, frosty winter, and much snow; 1269-70; 1263-4, very severe frost, horses and people went over the Thames; 1253-4; 1250, a rigorous and long winter, very great snows; W. A., 1234-5, a great frost destroyed the corn and herbs; 1233-4, frost lasted till Candlemas; S., 1229, severe winter, horses and carriages went on the ice, great snow; S., 1225-6; 1209, a long and hard winter, followed by dearth; 1204-5, such frost from January to March that the ground could not be tilled; B. S., 1200-1; 1179; 1175-6, fishes both in sea and fresh water died through sharpness and vehemency of that frost; 1154; 1149-50, intense frost, Thames so bound in frosty chains that from December to March horses and carriages used it as a highway; L. B., 1125, frost so intense that eels were forced to leave the water, and were frozen to death in the meadows; 1115-6, winter very extreme cold, with frosts so severe as no man living remembered; S., 1100-1, long and severe winter; S., 1095-6, a most severe winter, all rivers so frozen that horses and loading went over; 1093-4; W. S., 1069-70, extreme hard winter; A. S., 1059-60; B., 1045-6, winter more severe than ever remembered, men, cattle, fowls, and fish died; 1020, many people killed by severe, cold winter; S., 994-5, ice frozen so hard on ponds and rivers that most fish died; 975-6, a most rigorous strong frost November to March; S., 929, a bitterly cold winter; 874-5, earth covered with snow and ice November to March;

864, a sharp and long frosty winter; S., 823-4, a bitter, sharp, and long winter, a load of snow fell which lay 29 weeks; B. S., 764, marvellous great snow, and extreme frost; 759-60, great frost from October 1 to February 26; 695, Thames frozen 6 weeks; 670, most severe and long winter, killed much people and cattle; 604, most severe and rigorous, sea frozen and fishes killed; 554 and 545, cold so intense that birds and wild beasts could be caught by hand; 525, Thames hard frozen for 6 weeks; 474, frost with great snow for 4 months; 359; B. L., 329 and 290-1, English rivers frozen 6 weeks; 250 or 230, Thames frozen 6 weeks; 220, great frost in England lasting 5 months; 134, Thames frozen 2 months.

Total, 62 frosts.

The second list (winters outside the prescribed periods) is as follows:—

1572-3; 1547-8; 1536-7; 1407-8; 1352-3; 1337-8; W. S., 1291-2; A. S., 1281-2; 1221-2; 1207; B. S., 1201-2; B. S., 1142-3; 1121-2; 1076-7; B., 1047-8; 987-8; 962; C., 892; 827; 507-8.

Total, 20 frosts.

The third list (of doubtful or variable winters) is as follows:—

1241; S., 1141; 1128; S., 1111; A. W., 1086; W. S., 1066; 1063; A. W., 1061; 998; B. L., 991; B., 981; S., 956; 923; S., 913; 908; C., 898; 821; 443; B. S., 173; L. B., 153.

Total, 20 frosts.

It is interesting to notice that in the first 9 centuries, out of 26 recorded frosts, only 3 are proved to have fallen outside the prescribed numbers.

Now taking the whole 19 centuries, and omiting the doubtful dates, we get 120 frosts which have fallen within the prescribed dates against 31 which have not—a very striking result, when we consider that if frost fell in the same proportion in all years, we ought to have 80 in the second list when we have 120 in the first.

There are of course many severe winters in the earlier centuries of which no record now exists, but it is reasonable to suppose that a note was made of the majority of the most severe; and there is no ground for imagining that, if the others had been recorded, they would have fallen in the several years in any different proportion from those that are recorded.

Every winter I can find, after diligent search, of which any record of its great severity in England remains, has now been mentioned, and there appears to be no doubt that the list of the frosts prior to 1600 strongly confirms the conclusions drawn from the list of those subsequent to that date.

If it be asked why a maximum severity of frost should thus appear to recur about twice every decade, and whether such a recurrence is not the result of an arbitrary division of dates, I can only answer that I have in this paper only made a record of clearly ascertained facts, and that my theory is founded on that solid basis. And after all it seems no more strange that there should be evidence of a short period in matters meteorological than that there should be such in matters astronomical, for the laws that regulate the weather are doubtless just as definite and exact as those that regulate the movements of the celestial bodies, though in the present imperfect state of our knowledge the former appear to be less

clearly defined. Perhaps our descendants may be able to unravel these laws more completely, and show the causes of what at present appear to be exceptions to them.

ADDENDUM—FEBRUARY 19, 1901.

The winter here, fortunately for the poor but unfortunately for my paper, has been a mild one. But even the best rules have their exceptions, and I have not stated that those laid down in this paper are without a few exceptions; only, from my point of view, the exception this time has happened to fall at an inconvenient period. If the paper had been read just before the extremely severe winter of 1890-91, followed, as it was, in due order by the extremely severe winter of 1894-95, whose attention would not have been attracted to it? And I venture to predict that in fifty years' time our descendants will be hunting up the paper again, and considering how curious it is that these rules still hold good! Strangely enough, there was a failure at the beginning of last century, viz. between 1804 and 1806. This century is still in its infancy, and considering the record of last century, viz. twenty-three winters that followed these rules, and only three that did not, it would be very unwise hastily to assume because of one exception that there is nothing in them, for exactly the same thing might have been said at the beginning of last century. Rather, the paper must stand by for a time, and be left for future years to decide to what extent the rules given are trustworthy.

And even though the winter has been mild in the British Islands, that has been by no means the case to the east of us; *e.g.* in the *Standard* for the 18th instant I read:—

> No one remembers such a long continuance of low temperature and heavy snowfalls as have occurred through Germany during the last five or six weeks. The snow in the mountainous districts lies so deep that all traffic is interrupted, and as soon as the roads are cleared they are blocked again. In the higher districts the snow is 15 feet deep or more. Game animals come to the villages for food, and are often captured by the peasants.

This is by no means an isolated case, for from all parts of the Continent—Sweden, France, Russia, Italy, Spain, etc.—have come constant reports of intensely severe weather, which have been printed at intervals during the whole winter, day after day, in our leading papers. We have, as it were, lain all along just on the western outskirts of this severe weather; indeed, since February set in, its area has tended more and more to embrace us too, for the present month is one of the most winterly we have had for some years.

With regard to the definition of a severe winter, it has been suggested that the total number of frosts should form the basis for consideration, but this is not altogether satisfactory, for they may all have been of a slight nature; on the other hand, if we consider only the severe frosts, then a short spell of very cold weather might be reckoned as a severe winter, and this is equally unsatisfactory; rather we ought to combine these two points, so that both length and intensity might be taken into account; and this, I think, might best be done by con-

sidering the total number of degrees of frost in the air during winter. I should suggest that a winter should be considered a se one in which there have been upwards of 250° of frost in the between the beginning of November and the end of February. In last severe winter we had, viz. that of 1894-95, there were at Croy 416° of air-frost between these dates, and in the winter of 1890-91, next severe one before this, there were 489°; but both these win were excessively severe. Of course it is impossible to apply this to the majority of the winters spoken of in my paper, as no record temperature exist; but those winters must have been severe to wl the appended remarks could be applied, and it is reasonable to sup that the winters so remarked upon were the only winters in re centuries that attracted attention by their severity.

DISCUSSION.

The President (Mr. W. H. Dines) said that the paper bore evidence of g pains being expended on it, and they must thank Mr. Watson for his tro in working it up. Some of the quotations afforded valuable informatio the climate of past years. When definite statements were made, such "Coaches plied from Westminster to the Temple" (*i.e.* on the Thames) in the streets," 1683-84; and "Thames frozen for three months and a fair l on it," 1715-16,—we had no reason to doubt the truth of the statements. frequent recurrence of reports of this kind relating to the earlier years of series confirmed an opinion he (Mr. Dines) had long held, namely, that winters were becoming slowly but surely milder than they used to be; for Thames had not been fairly frozen over in London since 1813-14, and possibility of skating continuously for six weeks on a shallow pond, no speak of a river like the Thames, was now of very rare occurrence. The that these hard winters seemed to come mostly at certain dates was very markable, and Mr. Watson had certainly made out a case for their doing but it seemed so extremely improbable that there should be any special re for this, that it could only be looked upon as one of those curious coin ences that were so often turning up in meteorology.

Mr. W. B. Tripp remarked that the state of the Thames was very diffe before the removal of old London Bridge about 1825 to what it was now; London Bridge, acting as a half tidal dam, greatly diminishing the range of tide, and probably accounting for the fact of the water freezing more often t it did now.

Mr. E. Mawley said that whatever might be thought of the conclusion which Mr. Watson had arrived, he considered they would all agree that paper contained the most complete record of cold winters in England that yet been compiled. The cold winters had evidently been selected with siderable impartiality. Nevertheless, from a scientific point of view, it wa be regretted that, at all events for the winters of the past century, some c definition had not been given as to what the author meant by a "se winter." There were so many different ways of gauging severe winters tha became necessary, whatever test be adopted, that the same test be applied each winter in the series. Mr. Watson's deductions were in the main suppo by the Greenwich records for the last 60 years. Taking all the winters du that period, and grouping them in the same way that the author had done, mean temperatures of the different groups and their departures from the si years' average came out as follows:—

Mean temperatures at Greenwich of the different groups, and their departures from the average during the 60 *winters* 1841-42 *to* 1900-01.

Winter.	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–0
Mean temperatures .	37°·7	40°·1	40°·4	39°·6	36°·6	39°·9	39°·0	39°·8	40°·7	38°·0
Variation from Average	−1·5	+0·9	+1·2	+0·4	−2·6	+0·7	−0·2	+0·6	+1·5	−1·2
No. of Cold Winters (winters below the average in mean temp.)	4 out of 6	2 out of 6	1 out of 6	2 out of 6	5 out of 6	3 out of 6	3 out of 6	2 out of 6	2 out of 6	4 out of 6

That cold winters favoured in such a marked manner certain years in each decade during the last sixty years may be, and doubtless is, after all, only a coincidence; but if so, it is certainly a very remarkable and noteworthy one.

Mr. C. Harding remarked that apparently Mr. Watson had not known of a paper by Mr. Glaisher in which he mentioned the cold winter of 1771-72, in which the three months January to March were 3°·3 below the average. There were also great falls of snow from the middle of January to March. In the winter of 1885-86 there was skating from December to March, which he believed was the only winter in which such a thing had been possible during four months since the records of the Skating Club had commenced. No doubt Mr. Watson's list of severe winters was a very complete one, and the digit figure was an easy aid to memory.

Dr. H. R. Mill inquired whether Mr. Watson had considered the question of periodicity of severe winters in connection with the eleven years sunspot cycle, especially with reference to the method recently advocated by Sir Norman Lockyer in his paper before the Royal Society on "Solar changes of Temperature and variation in Rainfall in the region surrounding the Indian Ocean."

Mr. R. Bentley inquired if Mr. Watson had made any examination of the works of George Mackenzie of Perth on periodicity of weather, published more than eighty years ago. After many years' research, Mackenzie claimed that "the commencement and termination of years of scarcity or abundance are undoubtedly ascertainable with the recurrence of favourable or unfavourable seasons." Mackenzie received for his researches the thanks of the English Board of Agriculture, and Baron Humboldt was asked by the French Institute to report upon his system of weather, and his "cycle of the winds."

Mr. F. J. Brodie said it would be interesting to feel assured that the paper dealt only with severe frosts occurring in this country. In the postscript Mr. Watson had claimed in support of his statement as to the winters ending with 1 being usually severe, that the present winter, though fairly mild over England, had been much colder over the Continent. It seemed to him (Mr. Brodie) that after deducting all the winters comprised within years ending with 4, 5, and 6, and these ending with 9, 0, and 1, very few others remained in which the severe frost would have a chance of putting in an appearance.

Mr. A. E. Watson, in reply, said he had not seen Mr. Glaisher's paper, referred to by Mr. Harding, and was very sorry not to have done so. He had not studied the question in relation to sunspot cycles, but thought the matter very interesting and full of suggestion. He had confined himself entirely to frosts in England, and had only referred to the Continent in the postscript to show the different conditions existing there and here, and how narrowly we had escaped a severe winter. The quotations in the paper were exact copies from the original books, and the authority was given in every case.

The Death of Queen Victoria.

At the Meeting of the Society on February 20, the President (Mr. W. H. Dines), in moving that a loyal and dutiful Address of Condolence and Homage be presented to His Majesty The King, said [all the Fellows present standing]—

That he thought there could be but one opinion on the subject among the Fellows. The increase of comfort and prosperity during the reign of our late beloved Queen was matter of common knowledge, and he need not refer to it. He thought that it would be difficult to find any one who had been so much respected, and who had so fully earned such respect. He could remember the time when the Queen's actions had not always been received by the nation without criticism, but that of recent years, such was the love and respect borne her, it seemed as though whatever she had done had been accepted as the best and wisest, simply because she had done it. The feeling towards the Crown during her reign had entirely altered, and there was no doubt that the alteration was due to her personal character and influence. There was but one general feeling about the loss they had sustained, and the presentation of the Address was far more than a mere matter of form. They trusted, however, that in her successor King Edward VII. they had a King who would walk in her ways, and extend to Science the same liberal patronage that she had always shown.

The following Address was adopted:—

To the King's Most Excellent Majesty.

The Humble Address of the President, Council, and Fellows of the Royal Meteorological Society.

May it please Your Majesty—We, Your Majesty's most dutiful and loyal Subjects, the President, Council, and Fellows of the Royal Meteorological Society, desire to be permitted to tender our sincere and heartfelt sympathy to Your Majesty on the loss which Your Majesty and the Nation have recently sustained, in the demise of Your Royal Mother, Her late Majesty Queen Victoria.

Words would be quite inadequate to express our sense of the unexampled blessings which have accrued to the Nation during the lengthened Reign of Her who has so lately passed away. This period has been marked by unparalleled progress in the material welfare of Her vast Dominions, and the advances of Science, to which She ever paid intelligent attention, have been unprecedented. She was indeed a Mother to Her people, who with one voice arise and call Her Blessed.

At the same time the Society desires to be permitted to express its thankfulness that the Crown has descended to One who has already proved Himself an active Patron of Science, and Who, we doubt not, will follow in the footsteps of His august and revered Mother.

Given under the Seal of the Society, this Twentieth day of February, in the year of Our Lord One thousand nine hundred and one.

W. H. Dines, *President.*

Francis Campbell Bayard, } *Secretaries.*
Edwd. Mawley, }

L. S.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

January 16, 1901.

Ordinary Meeting.

Dr. C. THEODORE WILLIAMS, President, in the Chair.

ANTHONY J. DREXEL BIDDLE, 2104 Walnut Street, Philadelphia;
Rev. GUY JULIAN BRIDGES, Sutton Mandeville, Salisbury;
WILLIAM ALFRED BROWNE, LL.D., 4 Victoria Street, S.W.;
TATHWELL H. B. COLLINSON, Lyttelton, Horndean Road, Emsworth;
HENRY COX, Radipole Manor, Weymouth;
FRANCIS DAVIS, Whitwell, Elland, Yorks;
ALFRED DEED, Heathfield, Priory Lane, Blackheath;
GEORGE EVEREST ELLIS, 63 King William Street, E.C.;
Prof. J. W. LOWBER, LL.D., Austin, Texas, U.S.A.;
Capt. WILLIAM SMITH MAIN, 6 Osborne Terrace, Govan;
GEORGE SMEE ODLING, 18 Norham Gardens, Oxford;
FREDERICK EDWARD PIRKIS, R.N., The High Elms, Nutfield;
FLEETWOOD SANDEMAN, 80 Albert Hall Mansions, S.W.;
ROBERT W. SAUL, 5 Waveney Road, Lowestoft;
WILLIAM HENRY SYMONS, M.D., Guildhall, Bath; and
ALBERT GEORGE THOMPSON, 4 Strathmore Gardens, Bognor,
were balloted for and duly elected Fellows of the Society.

January 16, 1901.

Annual General Meeting.

Dr. C. THEODORE WILLIAMS, President, in the Chair.

Mr. F. DRUCE and Mr. A. J. HANDS were appointed Scrutineers of the Ballot for Officers and Council.

Mr. F. C. BAYARD read the Report of the Council and the Balance-Sheet for the year 1900. [This will appear in the next number of the *Quarterly Journal.*]

It was proposed by the PRESIDENT, seconded by Mr. F. C. BAYARD, and resolved: "That the Report of the Council be received and adopted, and printed in the *Quarterly Journal.*"

It was proposed by Mr. E. MAWLEY, seconded by Dr. R. H. SCOTT, and resolved: "That the best thanks of the Society be presented to Dr. C. THEODORE WILLIAMS for his able, courteous, and generous discharge of the duties of President during the Jubilee year, 1900.

"That a copy of this Resolution be engrossed and sealed with the Society's Seal, and presented to Dr. C. Theodore Williams" (see p. 156).

It was proposed by Mr. A BREWIN, seconded by Mr. W. N. SHAW, and resolved: "That the thanks of the Society be given to the Officers and other Members of the Council for their services during the past year."

It was proposed by Major L. FLOWER, seconded by Mr. J. HOPKINSON, and resolved: "That the thanks of the Society be given to the Standing Committees and to the Auditor, and that the Committees be requested to continue their duties until the next Council Meeting."

It was proposed by Dr. H. R. MILL, seconded by Mr. H. N. DICKSON, and

resolved: "That the most cordial thanks of the Royal Meteorological Society be communicated to the President and Council of the Institution of Civil Engineers for having granted the Society free permission to hold its Meetings in the rooms of the Institution."

The PRESIDENT then delivered an Address on "THE CLIMATE OF NORWAY AND ITS FACTORS" (p. 105).

It was proposed by Mr. F. GASTER, seconded by Capt. D. WILSON-BARKER, and resolved: "That the thanks of the Society be given to Dr. C. THEODORE WILLIAMS for his Address, and that he be requested to allow it to be printed in the *Quarterly Journal.*"

The Scrutineers declared the following gentlemen to be the Officers and Council for the ensuing year:—

PRESIDENT.

WILLIAM HENRY DINES, B.A.

VICE-PRESIDENTS.

RICHARD BENTLEY, F.L.S., F.R.G.S.
RICHARD INWARDS, F.R.A.S.
BALDWIN LATHAM, M.Inst.C.E., F.G.S.
Sir CUTHBERT EDGAR PEEK, Bart., M.A., F.R.G.S., F.R.A.S.

TREASURER.

CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P.

SECRETARIES.

FRANCIS CAMPBELL BAYARD, LL.M.
EDWARD MAWLEY, F.R.H.S.

FOREIGN SECRETARY.

ROBERT HENRY SCOTT, M.A., D.Sc., F.R.S.

COUNCIL.

Capt. ALFRED CARPENTER, R.N., D.S.O., F.Z.S.
WILLIAM HENRY MAHONEY CHRISTIE, M.A., C.B., F.R.S.
RICHARD HENRY CURTIS.
HENRY NEWTON DICKSON, B.Sc., F.R.S.E., F.R.G.S.
WILLIAM ELLIS, F.R.S., F.R.A.S.
Major LAMOROCK FLOWER.
CHARLES HAWKSLEY, M.Inst.C.E.
Capt. MELVILLE WILLIS CAMPBELL HEPWORTH, F.R.A.S.
HUGH ROBERT MILL, D.Sc., F.R.S.E., F.R.G.S.
WILLIAM NAPIER SHAW, M.A., F.R.S.
HERBERT SOWERBY WALLIS.
Capt. DAVID WILSON-BARKER, F.R.S.E., F.R.G.S.

Dr. C. THEODORE WILLIAMS having left the Chair, it was taken by Mr. W. H. DINES, the newly elected President, who thanked the Fellows for having elected him to that office.

February 20, 1901.

Ordinary Meeting.

WILLIAM HENRY DINES, B.A., President, in the Chair.

PATRICK Y. ALEXANDER, The Mount, Batheaston, Bath;
Rev. JACOB BENJAMIN ANAMAN, Saltpond, Gold Coast;

ALFRED BALDWIN, M.P., Wilden House, near Stourport;
SAMUEL BAKEWELL BATES, Mingin, Chindwin, Upper Burma;
ROBERT CLARKE, San Remo, Dawlish;
JOHN WAUGH FORRESTER, 115 Leadenhall Street, E.C.;
THOMAS HENNELL, 6 Delahay Street, Westminster;
LEONARD CLEMENTS HENRY, Acrise, Gold Coast;
GEORGE HENRY BURMAN MATTHEWS, Old Calabar, West Africa;
JOHN STEWART REMINGTON, Aynsome, Grange over Sands;
The RAJAH A. V. JUGGA ROW, Daba Gardens, Waltair, India; and
SAMUEL SLEFRIG, B.Sc., Waterloo Road, Shepton Mallet,
were balloted for and duly elected Fellows of the Society.

On the motion of the PRESIDENT, it was resolved that an Address of Condolence and Homage be presented to His Majesty THE KING (see p. 152).

The following communications were read:—

1. "REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1900." By EDWARD MAWLEY, F.R.Met.Soc. (p. 117).

2. "A REVIEW OF PAST SEVERE WINTERS IN ENGLAND, WITH DEDUCTIONS THEREFROM." By ALBERT E. WATSON, B.A., F.R.Met.Soc. (p. 141).

Mr. W. MARRIOTT exhibited lantern slides of diagrams prepared by Mr. C. Aburrow, M.Inst.C.E., showing the monthly rainfall and the absolute maximum and minimum temperatures at Johannesburg for several years past.

CORRESPONDENCE AND NOTES.

Sydney Observatory Meteorological Service.—There has been no increase of this staff during the past year, but much more has been done than during 1898, owing to improvements in the method of working and experience. The work is, however, expanding rapidly, and the public are very much interested in the Service generally, and especially in improvement of charts and information. During the year the Weather Chart has been entirely remodelled and improved. The Rain Chart has also been very much improved. The public take a keen interest in the Rainfall, because it affects business so directly through the stock and farming products, and the contents of the Rain Chart are eagerly watched for forecasts of coming rain, in which they are seldom disappointed.

A less wide circle of the public are interested in the Weather Chart showing all meteorological conditions over Australia and forecasts of coming weather and rain. The chart appears first at mid-day with a forecast from observations of some States, and another edition of the chart completed, and another forecast with latest information. In stormy weather sailors as well as landsmen find their way to the charts, which are exhibited in several places in the city; and the forecasts are telegraphed to all the coast stations and all the larger inland towns, from which they are distributed in some cases by telephone. In this Service 18,000 charts are published in the year. In the Rain Service 5000 charts, showing daily and monthly rain, have been distributed. In exchange for these we get from other observatories all over the world many very valuable publications. We publish the annual volume showing rain, etc., all over the colony and all conditions affecting stock. The 1898 book has been printed and published, and 1899 is ready for the printer; 1855 Rain Reports have been distributed, and 700 copies of other publications have been published.—H. C. RUSSELL, Government Astronomer, January 29, 1901.

Illuminated Address to Dr. C. T. Williams.—The accompanying illustration is reproduced from a photograph of the Illuminated Vote of Thanks to Dr. C. Theodore Williams referred to on p. 153.

Some of the colours were such that they would not act on the photographic plate, and so do not come out in this reproduction.

Daily Weather Reports and Barometer Comparisons.—For some time I have been impressed with the idea that the public in general are not making practical use of the *Daily Weather Report* issued by the Meteorological Office, which may be had for £1 a year. The Chart, together with the probable changes given on p. 3, are very instructive.

In 1890 Stanford published a little book I wrote *On Weather Forecasting for the British Islands*, and this is also applicable to the whole of North-Western Europe.

Since that date I have carefully recorded a standard mercurial barometer and two aneroids—one a small pocket instrument, the other much larger. On Wednesday in each week, at 8 a.m., observations were recorded by the three instruments, and compared with that for London given in the *Daily Weather Report*. Generally the observations of seven to ten weeks (though sometimes fewer) were brought together and meaned. This mean, compared with the London observations, gave a certain difference, the result of the fact that the London observations were reduced to sea-level whilst mine were not. From this difference I calculated the height of my barometer above the level of the sea. The mean of a large number of observations was 126 ft., whilst the extremes were only four above or below that mean. I found that by taking an eleventh from the thousandths of an inch contained in that difference, I got the number of feet my barometer was above the level of the sea.

Finding such an agreement in the heights calculated in London, I decided, by careful comparisons, to get the error of my pocket aneroid, and, when away from London, to compare its readings with those of the barometer at the nearest station recorded in the *Daily Weather Report.* I have two such records before me: one at Studland, near Swanage, the other at Brasted Chart. The nearest Weather Report Station near Studland was that of Portland Bill, whilst London was the nearest to Brasted Chart. The mean result of six weeks' daily observations at Studland gave my aneroid to be 174 feet above the sea; whilst that of six weeks at Brasted Chart was 637 feet. The Ordnance Map shows it to be about 630 feet. Following I give a table showing the growth of the errors of my aneroids, and another showing the result of the daily observations at Brasted:—

ANEROIDS' ERRORS.

Dates.		Means of all Observations.		Means when Barometer was highest.		Means when Barometer was lowest.		Mean Height of Mercurial Barometer above Sea-level.[2]
		A[1]	B[1]	A	B	A	B	
		in.	in.	in.	in.	in.	in.	feet.
1897. May 5	to June 30	− ·12	+ ·21	− ·13	+ ·22	...	...	123
Sept. 22	,, Nov. 24	− ·15	+ ·33	− ·12	+ ·31	− ·16	+ ·32	128
1898. Feb. 9	,, March 30	− ·17	+ ·35	− ·14	+ ·35	− ·18	+ ·36	125
April 6	,, May 25	− ·18	+ ·33	− ·14	+ ·35	− ·22	+ ·30	128
June 1	,, July 20	− ·18	+ ·31	− ·15	+ ·32	− ·20	+ ·33	126
Sept. 7	,, Sept. 28	− ·19	+ ·32	− ·19	+ ·30	− ·19	+ ·35	124
Oct. 5	,, Nov. 25	− ·19	+ ·36	− ·17	+ ·36	− ·22	+ ·37	126
1898 1899 } Nov. 30	,, Jan. 18	− ·18	+ ·37	− ·14	+ ·38	− ·23	+ ·35	128
1899. Jan. 25	,, March 22	− ·18	+ ·39	− ·14	+ ·40	− ·23	+ ·39	129
March 29	,, May 17	− ·19	+ ·36	− ·18	+ ·37	− ·22	+ ·35	130
May 24	,, July 26	− ·21	+ ·32	− ·19	+ ·31	− ·24	+ ·30	...
Nov. 8	,, Dec. 27	− ·21	+ ·41	− ·18	+ ·41	− ·24	+ ·41	125
1900. Jan. 3	,, March 14	− ·19	+ ·43	− ·17	+ ·43	− ·21	+ ·43	122
March 21	,, May 30	− ·22	+ ·39	− ·18	+ ·37	− ·26	+ ·41	126
June 6	,, July 25	− ·23	+ ·35	− ·22	+ ·35	− ·25	+ ·32	127
Sept. 12	,, Nov. 14	− ·23	+ ·41	− ·19	+ ·41	− ·27	+ ·41	127
1900 1901 } Nov. 21	,, Jan. 23	− ·24	+ ·44	− ·21	+ ·45	− ·26	+ ·44	129
						Mean .	.	126

	Of all Observations.		Of 2 or 3 Highest Readings.		Of 2 or 3 Lowest Readings.	
	A	B	A	B	A	B
Means in 1898[3] . .	− ·18	+ ·35	− ·16	+ ·34	− ·21	+ ·34
Means in 1899 . .	− ·20	+ ·37	− ·17	+ ·37	− ·23	+ ·36
Means in 1900 . .	− ·22	+ ·40	− ·19	+ ·40	− ·25	+ ·40

As already remarked, when in the country for a summer holiday, I have been in the habit of recording my pocket aneroid at 8 a.m. for six days in the week, together with the temperature, wind, and weather, and comparing my

[1] "A" represents my small pocket aneroid made by James Pitkin, London. "B" represents my large aneroid made by Negretti and Zambra, London. The observations from which these results were obtained were taken at 8 a.m. every Wednesday.

[2] The mean height of my mercurial barometer above sea-level was obtained from the difference between the corrected reading of that barometer and the London observation given on the *Daily Weather Report* published by the Meteorological Office, which is always reduced to sea-level, whilst mine is not.

[3] The means of the observations in each of the years 1898, 1899, and 1900 show a yearly increase of ·02 in. in the error of the small aneroid (A), and of ·03 in. in the error of the large aneroid (B). The means when the barometer was high compared with those when it was low show that the error of the small aneroid was about ·06 in. larger when the barometer was low than it was when it was high. The error of the larger aneroid does not seem to have been affected by variations in the height of the barometer.

aneroid observations with those of the barometer at the nearest station on the Daily Weather Chart. In the summer of 1899 I was at Studland, near Swanage, and compared my observations with those of Portland Bill, which is about 23 miles in a straight line from Studland. The mean result gave 174 feet as the height of the house I lived in above the sea-level. There was a very fair agreement between the daily results.

In 1900 I was at Brasted Chart, which is about 19 miles in a straight line from London, with which station I compared my observations and got the following results:—

1900.	Mean Corrected Reading of my Pocket Aneroid.	Mean Reading of the London Barometer reduced to Sea-level.	Difference of Readings.	Height of Brasted Chart above Sea-level.[1]
	in.	in.	in.	ft.
July 30 to Aug. 4	29·140	29·810	·670	609
Aug. 6 ,, Aug. 11	29·180	29·880	·700	636
Aug. 13 ,, Aug. 18	29·520	30·220	·700	636
Aug. 20 ,, Aug. 25	29·050	29·730	·680	618
Aug. 27 ,, Sept. 1	29·490	30·220	·730	664
Sept. 3 ,, Sept. 8	29·520	30·250	·730	664
Means	29·317	30·018	·702	638[2]

HENRY TOYNBEE.

Crowing of Pheasants during Thunderstorms.—Mr. R. J. Purdy, of Woodgate House, Aylsham, Norfolk, reports that during a very distant thunderstorm on October 5, 1900, he heard the pheasants cry immediately after the report of the distant thunder. Mr. Purdy also says: "I have observed this on many occasions, and several times calculated the distance of the storm by noticing the interval carefully between the lightning flash and the call, allowing a little over four seconds to the mile, and found afterwards the distance was nearly correct.

"I find this extract from my diary for April 4, 1900:—'Thunderstorm at 3 p.m., wind west, lightning at 7.30 p.m. to south; pheasants crowing after an interval of 170 seconds.' This storm passed to the south of Diss.

"All who have studied the habits of pheasants know how they respond to the report of a cannon many miles away. In fact, any booming sound will cause them to crow, provided it is not too near them."

[We should be glad to learn whether any one else has noticed the crowing of pheasants during thunderstorms.—EDITOR.]

Extraordinary Mirage.—We have received, through Mr. F. Napier Denison, of the Meteorological Office, Victoria, British Columbia, a copy of the *Victoria Daily Times*, January 26, 1901, which contains an illustration of a remarkable mirage known as "The Silent City of Alaska." It is said to appear every year on the gigantic glacier of Mount Fairweather. This phenomenon has engaged the attention of scientists, and up to the present time it has baffled all investigation. The scene has been known to the Alaska Indians of the locality for generations, and has been a common subject of speculation among them.

The photograph was shown to some Alaska Indians by Capt. Foot of the *Danube*, who brought it down to Capt. Walbran, and they instantly recognised it as the famous city in the clouds.

The phenomenon is seen between 7 and 9 o'clock between June 21 and July 10, and the scene never varies excepting for slight changes in the buildings and

[1] The height in feet is roughly found by subtracting an eleventh from the thousandths of an inch in the difference of the readings of the barometer and the aneroid.

[2] The Ordnance Map gives the height to be about 630 feet above sea-level.

other prominent landmarks. It is believed that the mirage is a representation of the city of Bristol, England. That it is a seaport is shown by the mast of a vessel, while a tower, an exact duplicate of that of St. Mary Redcliff, appears in the background.

The earthquake of last year broke up the Muir glacier over which the route to the mountain lies. It is a distance of about 15 miles from Muir glacier bay to the scene of the phenomena. A scientific party from San Francisco will investigate it next May.

The distance between Bristol and Mount Fairweather is about 2500 miles. The longest distance a mirage has been seen hitherto is 600 miles.

Frost Fronds.—On the morning of January 29, as I was walking from Hampstead down Haverstock Hill into London, about 9.30, my attention was attracted by the "frost fronds" on the flags of the footpath. I see instances not unfrequently, and have called attention to one variety, where they form divergent groups, like the sticks of a partly opened fan, resembling the well known crystals of actinolite obtained on the southern side of the St. Gothard Pass (see *Proc. Roy. Soc.* lxiii. p. 217, and *Quart. Journ. Geol. Soc.* liv. p. 368); but those now mentioned were characterised by unusual delicacy and grace. They formed groups, often half a yard in diameter, composed of frond-like radiating tufts, made up of thin stems or acicular crystals (often some 4 ins. long and about the thickness of a bodkin) beautifully curved; this almost invariable bending of the "blades" being the most marked characteristic. They resembled very delicate seaweeds, dried and displayed on a card as an ornamental group. In descending the hill I observed that the crystals became a little coarser and more like those already mentioned. Also that sometimes clots of frozen mud appeared near the junction of the fronds, as if a trefoil or quatrefoil leaf had been placed there to hide it. I attribute the unusual delicacy of the fronds to the fact that the previous evening had been showery, and so the pavement had been cleaned of all but the very finest mud, after which had come a drying wind and a frost. Thus crystallisation probably occurred in a very thin film of slightly turbid water and on a fairly smooth surface, so that opposition to it was comparatively slight, and the circumstances approached more nearly to the crystallisation of water on glass. I could not linger to make a minute study, as I was pressed for time, but write this in the hope that some one who can take photographs (which I cannot) will collect examples of "frost fronds," for I believe they would be helpful in interpreting crystal-building in rock masses.—T. G. Bonney, 23 Denning Road, Hampstead, N.W., *Nature*, February 7, 1901.

Monthly Pilot Charts of the North Atlantic and Mediterranean.—The Meteorological Council have commenced with the month of April the issue of *Monthly Pilot Charts* on somewhat similar lines to those which have for many years been issued from Washington. These charts are distributed gratis to observers for the Meteorological Office, and are on sale at the Mercantile Marine Offices at 29 seaports round the coast. The price is 6d. a chart, or 5s. for the year. The charts cover precisely the same area as their American brethren, but the information printed thereon is different. Our own charts give directions for navigating different waters, such as the Mediterranean, and also notes on winds, currents, storm systems and rollers, as well as memoranda about changes in pilot signals. We find no mention of derelicts or of whales, etc., such as appear in the American charts. We hail this new venture as a most spirited one, and wish it every success.

Temperature and Rainfall at Kaikoura, New Zealand, 1900.—Dr. John St. C. Gunn has sent the following particulars as to the temperature and rainfall which he recorded at Kaikoura, New Zealand, during 1900. Kaikoura, which is on the east coast of South Island, is in lat. 42° 26′ 30″ S. and long.

173° 45′ E., and is 7 miles distant from the Kaikoura ranges, which rise to a height of 7000 feet above sea-level.

1900.	Temperature. Extremes. Highest.	Temperature. Extremes. Lowest.	Temperature. Means. Max.	Temperature. Means. Min.	Temperature. Means. Mean.	Rainfall. Total.	Rainfall. Greatest Fall in one Day.	Rainfall. No. of Rainy Days.
	°	°	°	°	°	ins.	ins.	
January	94	38	71	49	60·0	3·73	1·59	13
February	86	38	71	47	59·0	0·82	0·18	9
March	82	38	73	47	60·0	4·12	2·00	5
April	78	30	64	47	55·5	3·26	0·92	12
May	72	30	59	39	49·0	3.38	1·20	15
June	63	24	55	33	44·0	1.56	0·55	8
July	69	24	57	35	46·0	2·48	0·95	7
August	68	32	57	39	48·0	2·28	0·85	12
September	71	28	57	39	48·0	4·46	0·80	16
October	78	33	65	47	56·0	10·25	6·67	11
November	80	34	67	43	55·0	1·43	0·60	7
December	80	38	67	47	57·0	2·15	1·16	8
Year	94	24	63·6	42·7	53·1	39·92	6·57	123

Meteorological Observations at Brussels, 1833-99.—The *Annuaire Météorologique* for 1901 contains a valuable collection of tables giving the monthly and annual values of the principal meteorological elements at the Royal Observatory of Belgium for a period of sixty-seven years. The observations from 1833 to 1890 were made at the old Observatory at Brussels, and those from 1891 to 1899 at the new Observatory at Uccle.

The monthly and annual averages of some of the elements are given in the accompanying table :—

Meteorological Results, Brussels, 1833-99.

Month.	Temperature. Mean.	Temperature. Mean Max.	Temperature. Mean Min.	Temperature. Absolute Max.	Temperature. Absolute Min.	Relative Humidity.	Rainfall.	Amount of Cloud.	No. of Days of Rain.	No. of Days of Snow.	No. of Days of Hail.	No. of Days of Thunder.	No. of Days of Fog.
	°	°	°	°	°	%	ins.						
January	36·1	40·3	32·0	57·0	−4·4	86·3	2·13	7·5	14·4	6·2	0·7	0·2	9·6
February	38·8	43·5	34·0	64·8	2·1	82·0	1·85	7·2	13·2	5·9	0·8	0·2	6·6
March	42·3	48·4	36·0	69·8	8·6	72·7	1·93	6·9	14·8	6·1	1·6	0·6	5·7
April	49·1	56·8	41·4	78·4	24·6	64·1	1·85	6·3	15·5	2·0	2·0	1·2	3·1
May	55·9	64·8	47·1	87·3	30·6	61·9	2·20	6·4	16·4	0·4	1·4	2·7	2·2
June	62·6	71·2	53·8	94·5	39·2	63·9	2·56	6·5	16·2	0·0	0·7	3·8	1·5
July	65·1	73·6	56·7	95·4	44·4	65·2	2·91	6·5	16·8	0·0	0·4	4·1	1·3
August	64·2	72·3	56·3	94·3	42·6	66·3	2·95	6·3	16·6	0·0	0·3	3·8	2·8
September	59·2	66·4	52·0	88·0	37·0	71·7	2·56	6·0	15·7	0·0	0·5	1·8	5·7
October	51·4	57·2	45·5	77·0	27·5	78·3	2·80	6·7	17·9	0·3	0·9	0·6	8·3
November	43·2	47·8	38·7	66·4	11·8	83·6	2·44	7·3	17·2	3·1	0·7	0·1	9·5
December	37·8	41·9	33·8	59·5	1·6	87·6	2·36	7·5	15·4	4·9	0·7	0·1	10·7
Year	50·4	57·0	43·9	95·4	−4·4	73·6	28·54	6·8	190	29	11	19	67

Sunspots and Rainfall.—Sir J. Norman Lockyer and Dr. W. J. S. Lockyer have recently communicated a paper to the Royal Society on "Solar Changes of Temperature and Variations of Rainfall in the Region surrounding the Indian Ocean." This is the latest contribution to the meaning of sunspots. The paper starts with certain "Conclusions," of which the following contain the pith of the matter :—

1. It has been found, from a discussion of the chemical origin of lines most widened in sunspots at maximum and minimum periods, that there is a considerable rise above the mean temperature of the sun around the years of sunspot maximum, and a considerable fall around the years of sunspot minimum.

2. It has been found, from the actual facts of rainfall in India (during the South-west Monsoon) and Mauritius between the years 1877 and 1886, as given by Blanford and Meldrum, that the effects of these solar changes are felt in India at sunspot maximum, and in Mauritius at sunspot minimum. Of these the greater is that produced in the Mauritius at sunspot minimum. The pulse at Mauritius at sunspot minimum is also felt in India, and gives rise generally to a secondary maximum in India. India, therefore, has two pulses of rainfall, one near the maximum and the other near the minimum of the Sunspot Period.

3. It has been found that the dates of the beginning of these two pulses on the Indian and Mauritius rainfall are related to the sudden and remarkable changes in the behaviour of the widened lines.

The "Conclusions" close with a statement that Mr. John Eliot has seen the results and says his opinion is "that they accord closely with all the known facts of the large abnormal features of the temperature, pressure, and rainfall in India during the last twenty-five years."

The paper proceeds with an account of the widened lines, and then of the connection between sunspots and prominences. The results of our observations are then compared with rain tables from Mauritius, Cape Town, Batavia, and Cordoba, and a reasonable accordance is shown. For this and the final table showing the occurrence of the + and – rainfall pulses in other parts of the world (18 stations) we must refer to the paper itself.

Sounding the Ocean of Air.—This is the title of a book written by Mr. A. L. Rotch of the Blue Hill Meteorological Observatory, and recently published by the Society for Promoting Christian Knowledge. It is arranged in six chapters, and has a number of illustrations.

Chapter I. deals with the Atmosphere. The author traces the progress of meteorology from the time of Aristotle down to the present age. Clouds, balloons, and kites naturally supplement one another. While clouds indicate the direction and velocity of the air at different heights, yet the lower clouds often conceal the upper strata; or there may be no clouds at all, in which case balloons or kites will aid us to determine the drift of the currents. When there is little wind at the ground, or to reach heights of several miles, balloons must be employed, but otherwise kites are preferable in most cases. The thermal and hygrometric conditions of the free air can be ascertained only by personal observations in balloons, or by raising self-recording instruments with balloons and kites, and this latter method the author predicts will be the path of greatest progress.

Chapter II. is devoted to Clouds. The author treats fully of their formation and classification, and describes the methods adopted at Blue Hill and elsewhere to measure the heights and velocities of the various forms of cloud.

Chapter III. gives an account of many balloon ascents which have been made for meteorological purposes, and describes the results obtained therefrom.

Chapter IV. is devoted to *Ballons-sondes*, or sounding balloons, which carry self-recording instruments, but no observers. One such balloon, the *Cirrus*, on one occasion travelled 83 miles an hour and rose to 61,000 ft. The lowest temperature recorded was – 88° Fahr.

Chapter V. gives a history of kites and describes their application to meteorological purposes. It appears that kites were first used for scientific purposes in 1749, when Dr. A. Wilson and T. Melvill of Glasgow used them to lift thermometers. In 1882 Mr. Archibald revived the use of kites for meteorological observations, and employed them for ascertaining the increase of wind velocity with height. By means of the kites and apparatus at present employed at Blue Hill a meteorograph has been raised to a height of 12,070 ft. above sea-level.

In Chapter VI. the author gives the results of the kite-flights at Blue Hill. It is found that up to the height of a mile or two the air is drier during winter and at night, and damper during summer and in the daytime, than it is near the ground. The author says that the study of the data obtained indicate that the cyclonic and anticyclonic circulations observed in this latitude do not embrace any air movements at greater altitudes than 2000 metres, except in front of the cyclone, when the air appears to be carried upward to a great height. Above 2000 metres there are probably other weak cyclones and anticyclones, or secondary ones, with their centres at different places from those at the earth's surface and producing a different circulation of wind. The observations of the *cirrus* clouds at Blue Hill indicate that at their level exists a cyclonic circulation above the anticyclone apparent at the earth's surface. The shallowness of our anticyclones would be inferred from the great differences in speed of the general atmospheric drift; for since the velocity of the general drift from the West is more than thirty times greater at 10,000 metres than it is at 200 metres, a circulation of great depth could not endure long. Cyclones and anticyclones appear to be but secondary phenomena in the great waves of warm and cold air which sweep across the United States from periodic causes. The origin of cyclones and anticyclones is perhaps the most important problem remaining for meteorological study. The theory that they are produced by differences of temperature in adjacent masses of air, or, as it is called, the "convectional theory" of the American meteorologists Espy and Ferrel, is opposed by the observations on mountains in Europe which have been collected by Dr. Hann of Vienna. If the question can be solved by the use of kites, as seems to be foreshadowed by the results just stated, another foundation-stone will be laid in the science of meteorology, and the status of the kite established as an instrument of research.

RECENT PUBLICATIONS.

Annuaire Météorologique pour 1901. Publié par les soins de A. LANCASTER, Directeur du Service Météorologique de Belgique. Bruxelles. 8vo. vii + 576 pp. 1901.

For the past sixty-seven years the Royal Observatory of Belgium has regularly published an *Annuaire* devoted to astronomy and meteorology. Commencing with 1901, however, these services are to be separated, and each to have its own *Annuaire*. A large amount of valuable and interesting meteorological data has been brought together in this volume. Mons. A. Lancaster contributes papers on the following subjects:—(1) "Earthquakes in Belgium" (35 pp.). This gives a list of those recorded between the years 330 and 1896.—(2) "The Climate of the Ardennes" (27 pp.).—(3) "Results of the Meteorological Observations made at Uccle during the year 1900" (15 pp.).—(4) "The Climate of Belgium in 1899" (178 pp.). Mons. J. Vincent also communicates papers on the following subjects:— (1) "Historical Sketch of Meteorology in Belgium" (54 pp.).—(2) "Two old Meteorological Journals" (41 pp.). One of these journals was kept at Ciney from 1779 to 1810; and the other at various places by J. L. Hauregard between 1807 and 1830. The *Annuaire* also gives meteorological statistics for the Royal Observatory of Belgium for the sixty-six years 1833-99 (see p. 160).

Climat. N. DEMTCHINSKY, Editor. Oblong 4to. St. Petersburg. Nos. 1 and 2. March and April 1901.

Such is the title of the latest venture in the domain of weather prophecy, a journal which is to appear bi-monthly, costing 16s. per year, and is printed in

parallel columns in Russian, French, English, and German. The different versions do not exactly agree, for some paragraphs appearing in German are omitted in the English column. In the introduction the editor states that a year ago he published an essay "On the Possibility of the Exact Prediction of the Weather for any Period Ahead," and he professes himself to be a believer in lunar influence !! We had thought that that ghost had been laid in the grave of the late Lieut. Morrison, for it was on that rock that the Old Meteorological Society of London foundered.

In the first two parts there are mainly accounts of the author's attempts at a mathematical theory of his barometric wave, and other lucubrations of similar value from Prof. Glasenapp at St. Petersburg and from M. Poincaré. The wonder is where capital has been found to back up the issue of such an undertaking, as it is brought out in handsome style and copiously illustrated with curves and weather maps for several days in advance. Of course, like all weather prophets, he cites letters announcing brilliant success of his forecasts. He is not the only person who has adopted that practice.

Cornwall as a Winter Resort. 4th Edition. Revised by E. KITTO, Superintendent of Falmouth Observatory. 8vo. 1900.

As may be inferred from the title, the object of the author of this pamphlet is to call attention to the mild and equable nature of the climate of Cornwall, and to recommend it as a winter resort for invalids. Comparative meteorological data are given for Falmouth, Penzance, St. Ives, and Newquay ; and in further proof of the peculiar mildness and equability of the climate the author supplies long lists of exotic plants, etc., which flourish in the open air in Cornwall.

Lehrbuch der Meteorologie. Von Dr. JULIUS HANN. Parts I. to III. 8vo. Leipzig. Chr. Herm. Tauchnitz. 1901.

At last we have a text-book of Meteorology from the hand best qualified to prepare it. The work is in royal 8vo, and it is promised to be completed in about eight parts, of which three are already to hand. The book is thoroughly worthy of the reputation of its author, and it is simply indispensable for any serious student of our science. We can only say that if the language presents any difficulty to such a man, the sooner he learns German the better.

To give an idea of the conscientiousness with which Dr. Hann has carried out his task, and of the amount of knowledge evinced on every page, we need only state that for every important statement he cites the original paper in which the particular result has been published, laying under contribution most of the languages of the civilised world.

Parts I. and II., after the Introduction, are devoted to the subject of Temperature in all its bearings, while in Part III. Pressure is discussed and the treatment of Vapour is commenced.

In the Introduction, where we deal with the agencies acting on the atmosphere, we find all the most recent investigations of Lord Rayleigh, Sir W. Abney, and Mr. Aitken, merely to quote our own countrymen among the authors cited. *Inter alia*, we have the latest and most trustworthy results of actinometry and the determination of the solar constant.

On the subject of Temperature we have, firstly, the results of radiation from the sun and from the earth respectively. Then follows the consideration of diurnal range in the soil, and the atmosphere over land and sea, and by night and day. As an instance of the minuteness with which this is elaborated, we may cite a diagram showing the different curves for diurnal range with sea breeze and land breeze for Argos in Greece. We next find the annual range on land and sea. For this former we have no less than 24 stations represented by monthly means,

covering latitudes from lat. 6° S. (Batavia and Jaluit Island) to 37° S. (Auckland) and 82° N. (Grinnell Land). Under the head of non-periodic temperature variations we have a treatment of the question of the probable errors of deduced means and of the number of years required to give a true mean for any station. It is also shown that no secular variation of temperature of any character has been established, and that, *e.g.* at Newhaven, Conn., the commencement and end of winter, as indicated by ice on the Hudson River, has not changed between 1779 and 1865 (Loomis). We now come to the distribution of temperature at different levels, and have an account of the most trustworthy figures from mountain stations and from balloons and kites; and here we find a notice of the inversion of temperature with elevation, a phenomenon which constantly produces letters to the newspapers, when it occurs. As to the geographical distribution of temperature, this was of course the *magnum opus* of Dove, but Dr. Hann points out that J. D. Forbes has the credit of having as long ago as 1861 (*Trans. R. Soc. Ed.* vol. xxii. p. 75) laid down a theoretical formula for the relation of temperature to latitude, which agrees very well with the figures discovered by subsequent investigations. This shows that our author looks back to early papers for his statements. Lastly, we have the annual range of temperature at the level of the upper clouds; but this can only be shown by seasonal figures, representing the observations of isolated unmanned balloon or of kite ascents at different periods of the year.

The second part of the work deals with Pressure, and this naturally does not require nearly as detailed consideration as that which we have above described. We commence with the geographical distribution of mean pressure, the subject first attacked by Buchan. Then comes the vexed question of the diurnal range of the barometer, of which we have an exhaustive, up-to-date discussion of the most important papers on this difficult subject. This is followed by the consideration of the yearly period of the barometer and the relation of its changes to those of temperature anomaly.

We leave the subject of Vapour, which forms Part III. of the book, for a future notice.

We may say that the hand-book is copiously illustrated by diagrams, etc.

Meteorological Observations at Stations of the Second Order for the Year 1897. Published by Direction of the Meteorological Council, 1900. 4to. xiii. + 182 pp.

Returns from 78 stations are included in this volume, 40 being in England, 26 in Scotland, 3 in Wales, and 9 in Ireland. Detailed observations at 9 a.m. and 9 p.m. each day are given *in extenso* for 21 stations, which have been selected mainly as representative of the whole country.

Meteorologische Zeitschrift. Redigirt von Dr. J. HANN und Dr. G. HELLMANN. October 1900—January 1901. 4to.

The principal articles are:—"Windrichtung und Scintillation," von K. Exner (5 pp.). This is a criticism of a paper by Ventosa on the scintillation of stars, which he attributes to wind in the upper regions of the atmosphere. Dr. Exner has more than once returned to this criticism, and maintains that he has proved his case that any surface which is composed of a great number of particles, some bright and some dark, can reproduce the scintillation.

"Leuchtende und selbstleuchtende Nachtwolken," von A. Stentzel (9 pp.). This is an inquiry into the occasional luminosity of clouds, and the author comes to the conclusion that the phenomenon is always of an electrical character.

"Räumlicher Gradient und Circulation," von V. Bjerknes (10 pp.). This is a mathematical discussion of Dr. Möller's criticism of Dr. Bjerknes' paper of March last, "Das dynamische Princip der Cirkulations-bewegungen in der Atmosphäre."

"Ueber den Einfluss der Pflanzendecken auf die Wasser-führung der Flüsse," von Prof. Dr. E. Wollny (14 pp.). This is a brief résumé of the author's paper in the *Vierteljahresschrift* of the Bavarian Agricultural Council. The author puts forward a number of theses which have been derived from the tables in his former work, and points out the respective influence of permanent forest, of permanent grass, and of crops in general. These are given in the order of their importance. He winds up the paper with a recommendation to substitute permanent pasture for crops on land highly inclined, inasmuch as during the winter the cropped land is left quite bare, and there are no roots in it to bind the soil together when heavy rains come on.

"Ueber die Beobachtung von Irrlichtern," von W. Müller (10 pp.). This paper recounts several reports of Will o' the Wisp, beginning with Bessel's in the year 1838. One observer thrust a walking-stick into such a flame, but the ferule was not heated. Another succeeded in lighting tow on the end of a long rod. One thing comes out from all reports: no smell of phosphoretted hydrogen was perceptible, nor were rings of smoke seen, although in one case bubbles were seen to burst into flame.

"Ueber neuere Untersuchungen auf dem Gebiet der atmosphärischen Elektricität," von Prof. F. Exner (15 pp.). This is a report from the Physical Congress in Paris of 1900, and it deals chiefly with the requirements of the subject for future work. The author remarks that the material already collected comes mainly from Europe, but at almost all stations the electrograph is erected on a building without any attempt to obtain absolute values by the use of a portable electrometer observed in a perfectly open space. The only localities outside Europe where such absolute determinations have been secured are Luxor in Egypt, Ceylon, Tomsk in Siberia, and the oasis of Biskra. The annual period comes out everywhere, but Elster and Geitel have shown by their observations on the Sönnblick at the height of over 10,000 ft. that the amplitude nearly disappears, so that the phenomena are confined to the lower strata of the atmosphere. There are three types of daily period: (*a*) a double period, the commonest; (*b*) a single period; and (*c*) the almost total obliteration of any period. The type (*b*) is shown by Lisbon, the Polar Regions, and Mascart's observations. The marked absence of a period is shown by Ceylon and by Siberia in winter. Dr. Exner shows that the absolute period is essentially a phenomenon of the lowest strata; for he found it strongly marked at Lisbon, whereas, at a station less than 500 ft. above it, the amplitude was much reduced. As regards distribution of electricity with height, it is clear that as a rule the atmosphere is negative below and positive above; at the level of 18,000 ft. the sum of the earth and air charge is negative; and also that the atmosphere in fine weather exhibits frequent considerable changes in potential. The paper closes with recommendations of the most important points to be investigated by future observers.

"Zur Kenntniss der Kugelblitze," von Max Toepler (9 pp.). This paper on globular lightning points out that it is possibly related to a real form of discharge which he has described in *Wiedemann's Annalen* for 1897 and elsewhere. In it the discharge in air at ordinary pressure appears in the form of bright patches of light separated by dark spaces. It appears that each ordinary flash of lightning leaves a channel through the air in which electricity can move more freely than in the surrounding air; when the electricity streams continously between cloud and earth there is produced at several points a luminous mass which takes various shapes, sometimes that of a sphere. These spheres can be produced regularly, as explained in the paper, and they exhibit the phenomena.

"Bildung barometrischer Theilminima durch Föhne," von R. Billwiller (4 pp.). Dr. Billwiller, who is already well known for his researches on the Föhn, has given a good instance of the formation of a secondary depression on

the northern side of the Alps on March 19-22, 1900. The case is carefully worked out.

"Klima und Föhne der Dänemark-Insel, Scoresby-Sund," von A. Woeikof (6 pp.). In the years 1891-92 the Danish expedition under Herr Ryder carried on observations for ten months at this station, which is in 70° N., on the east coast of Greenland. Several instances of Föhn were reported, and moreover a most remarkable phenomenon was observed. On February 14, 1892, the barometer, corrected for gravity, reached 31·32 ins., a reading which has never before been recorded in the Arctic Regions on the shore of the Polar Sea and so near sea-level.

"Einige Ergebnisse der österreichischen Luftballons bei der internationalen Fahrt am 12 Mai, 1900," von J. Valentin (7 pp.). On May 12 last year one of the international balloon flights took place, and two balloons went up from Vienna: one called the *Jubilee Ballon*, the other *Wien*. The date was specially chosen as it was one of the cold days in May. The first balloon started at 4.25 a.m. and came down at noon north-east of Vienna. The second went up at 8 a.m. and came down at 1.7 p.m. north-east of Budapesth. What was the reason of such different flights? The first reached the level of 2000 metres, the second went up to more than double that height,—to 4500 metres,—so that clearly the first never reached the upper current which swept the balloon *Wien* to Hungary. Both balloons experienced several inversions of temperature. A map of isobars at sea-level and at that of 5000 metres shows a great contrast between the two systems; the former giving an anticyclone over Hungary, the latter one over Greece and the adjacent sea. For particulars we must refer to the original paper; but the author throws out the idea that the origin of the anticyclone which lay over Hungary at the time of the intense frost that year was due to the efflux of air from the Atlantic depression lying over icebergs drifting south near Newfoundland. He concludes that the May frosts are not a feature confined to the earth's surface, but a meteorological phenomenon of immense extent, which affects the entire atmosphere covering the whole of Europe up to the highest levels.

"Zur Einführung in die neueren Anschauungen über die Ursachen der Luftelektricität" (8 pp.). This paper on the origin of atmospheric electricity is not signed. It deals with the most modern theories of Elster and Geitel, and Pernter also of Mr. C. T. Wilson.

Among the shorter notices in the number is an interesting account of the Second International Congress on cannon-firing against hail, which took place in Padua. It was attended by Dr. Pernter, who is the narrator. The Congress was opened with the adoption by acclamation in a meeting of 1000 members of the following resolution: "The utility of firing to keep off hail is so certain that it does not admit of discussion." Such a resolution to open a discussion of the subject is not a little amusing. Dr. Pernter was afterwards informed that the resolution was intended for government consumption, in order that the grant for the firing should not be curtailed. As an appendix to this absurd business, we learn that definite areas are laid out in which firing will be carried out and all instances of hail noted: this will be organised by the Hohe Warte, Vienna.

Report of the British Association for the Advancement of Science. 8vo. London. 1900.

This volume contains the following reports and abstracts of meteorological papers read at the meeting of the Association at Bradford in September 1900:—"Meteorological Observatory, Montreal" (2 pp. and pl.).—"Solar Radiation" (9 pp.).—"Meteorological Observations on Ben Nevis" (7 pp.).—"Photographic Meteorology" (3 pp.).—"Seismological Investigations" (62 pp.

and 2 pl.).—"The Climatology of Africa" (8 pp.).—"Dew-Ponds," by Prof. L. C. Miall (7 pp.).—"Fifth Report on the use of Kites to obtain Meteorological Observations at Blue Hill Observatory, Massachusetts, U.S.A.," by A. Lawrence Rotch (1 p.).—"Charts illustrating the Weather of the North Atlantic Ocean in the Winter of 1898-99," by Capt. Campbell Hepworth (1 p.).—"The Rainfall of the Northern Counties of England," by J. Hopkinson (2 pp.).—"On the Relations of Radiation to Temperature," by Dr. J. Larmor (2 pp.).

Report of the Meteorological Council for the Year ending 31*st of March* 1900, *to the President and Council of the Royal Society.* 8vo. 158 pp. London. 1900.

The Report contains much detailed information upon the administration and work of the Meteorological Office. Upon the occasion of Mr. Scott's retirement the Council passed the following resolution:—

"That on the resignation by Mr. R. H. Scott of the post of Secretary, which he has held since the formation of the Meteorological Council in the year 1876, having previously served in a similar position, as Director, from the time of the institution of the Meteorological Committee in 1867, the Council desire to record their sense of the great value of his services during the prolonged period over which he has discharged the duties of the responsible post which he now quits, and to recognise cordially the constant attention he has bestowed on all the numerous details of the administration, to which the successful management of the business entrusted to the Council has been so greatly due."

The Report contains numerous appendices upon various subjects, among which may be mentioned:—(1) Correspondence relating to the continuation with the National Physical Laboratory of the relations hitherto subsisting between the Meteorological Office and Kew Observatory; (2) Further Correspondence relating to the maintenance of the Ben Nevis Observatory; (3) Method of dealing with Telegraphic Weather Intelligence; (4) Storm Warnings; (5) Method followed in dealing with Meteorological Returns from Land Stations; (6) Reports of Inspections; (7) Anemometer Experiments at Holyhead; (8) Researches on Atmospheric Electricity.

Symons's Meteorological Magazine. October 1900—March 1901. 8vo.

The principal articles are:—"The British Association Meeting, Bradford, 1900" (3 pp.). This article gives a brief notice of the meteorological papers read at the Bradford meeting.—"Studies of Cyclonic and Anticyclonic Phenomena with Kites" (5 pp.). This is the concluding part of an article (the first part of which appeared in the September number) based on a memoir by Mr. H. H. Clayton, issued by the Blue Hill Meteorological Observatory.—"The Weather of August—Cold Periods" (1 p.).—"Heavy Rainfall in Durham and Northumberland on October 26, 1900" (4 pp.). A very exceptional fall of rain and snow occurred in Durham and Northumberland on October 26, more than 3 inches being recorded at Durham, Sunderland, Newcastle, North Shields, and Morpeth. The fall was a prolonged one, lasting about 15 hours, and was accompanied by a gale, but neither lightning nor thunder is reported from the district. How severe the flooding and damage were may be gathered from the effect on the North Eastern Railway Company's System, several of their lines being completely blocked.—"Prevention of Hail by Cannonading" (3 pp.).—"Climatological Table for the British Empire for the Year 1899" (2 pp.). The maximum shade temperature was 113°·6 at Adelaide on February 12, whilst the minimum, −46°·5, was at Winnipeg.—"On Solar Changes of Temperature and Variations in Rainfall in the Region surrounding the Indian Ocean" (1 p.). This is a notice of a very important paper by Sir Norman Lockyer, K.C.B., F.R.S., and W. J. S. Lockyer, M.A., Ph.D., which was read before the Royal Society on

November 22, and which is referred to on p. 160.—"A Wet Autumn in Edinburgh" (1 p.).—"The Heavy Rainfall of December 30, 1900" (4 pp.). The area of heaviest rain was the valley of the Severn and of the Avon, and falls exceeding 3 ins. occurred over a strip of country stretching from near Bristol and Chepstow to Coventry.—"The Mild December," by H. Sowerby Wallis (1 p.).—"The International Meteorological Committee" (2 pp.). This is a report of the meeting held at St. Petersburg in September 1899.—"The Pressure of the Wind," by R. H. Curtis (6 pp.).—"Weather Records at Slough" (2 pp.).—"The Severe Frost of January 8 and 9, 1901" (1 p.).—"Recurrence of Cold and Warm Weeks": by A. B. MacDowall (1 p.).—"A Far-travelled Cyclone" (1 p.).

At the conclusion of Vol. XXXV., the editorship of this well-known Magazine has passed from Mr. H. Sowerby Wallis to Dr. Hugh Robert Mill.

Versuch einer Klassifikation der Klimate. Vorzugsweise nach ihren Beziehungen zur Pflanzenwelt. Von Dr. W. KÖPPEN. 8vo. 45 pp. and 2 plates. Teubner. Leipzig. 1901.

This work forms one of Dr. Albrecht Peuck's series of *Geographischen Abhandlungen*, in which so many valuable monographs have already appeared. Dr. Köppen at first cites the division of plant life over the globe into five groups: a scheme first proposed by De Candolle in 1874, and afterwards adopted by Drude, *Pflanzen geographie*, Stuttgart, 1890. The five groups are:—

A. Megathermen.—Great heat: the tropical vegetation.
B. Xerophilen.—Plants that love dryness: steppe plants.
C. Mesothermen.—Moderate heat: vegetation of sub-tropical regions.
D. Mikrothermen.—Little heat: the vegetation of temperate zones.
E. Hekistothermen.—Hardly any heat: the Arctic flora. From ἥκιστος, "the worst."

These five groups Dr. Köppen further subdivides into 24. For A he gives 2 groups, the *Lianen* or creepers, and the *Baobabs*, which require nearly constant rain.

For B there are 7 sub-divisions, of which the titles are *Garua*, or coast fog, *Simoon*, *Espinal*, *Tragacanth*, *Eastern Patagonian*, *Buran*, and *Prairie*.

For C there are 6 classes.—*Camellia*, *Hickory*, *Maize*, *Olive*, *Erica*, *High Savannahs*, and *Fuchsia*.

For D there are 3.—*Oak*, *Birch*, and *Antarctic Beech*.

For E there are 4.—The names are taken from the fauna, and are respectively the *Arctic Fox*, the *Penguin*, the *Yak*, and the *Chamois*.

Lastly, the 24th, F, has eternal snow and no vegetation.

Dr. Köppen then proceeds to point out the specialities of climate peculiar to each class, and of these we give two specimens:—

1. The Lianen Klima requires a constant rainfall of about 80 ins., and a temperature range of about 10°.

2. The Baobabs must have at least two months dry, a rainfall less than 80 ins., and a temperature range of, say, 20°.

We next come to the *Xerophil* groups, which comprise in their 7 sub-groups all the vegetation which frequents deserts and steppes, and are accustomed to endure long-continued drought.

In this way Dr. Köppen points out the main features of climate for each of his 24 groups, as characterised by the quantity and duration of precipitation and the general thermal conditions of the different seasons. To follow our author into all these particulars would soon overtask the space at our disposal. The whole treatise is a masterpiece of carefully digested study of the climatological conditions of the globe.

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CLIMATE AND THE EFFECTS OF CLIMATE.

BY HUGH ROBERT MILL, D.Sc., LL.D., F.R.S.E.

Abstract of a Lecture delivered to the Royal Meteorological Society, March 20, 1901.

THE unprejudiced, if uninstructed, intelligence of the "Man in the Street" is apt to find the meetings of a scientific Society a little dull, and it is a matter of some anxiety to those responsible for directing such a Society to combat this unpleasant reputation. Societies do not exist solely for the purpose of allowing experts to criticise each other, important as such proceedings may be; they have also a mission to perform to the unscientific world, which, although occupying the second place, is not to be overlooked. The number of well-educated persons capable of understanding and deriving pleasure from scientific discussions is yearly increasing, and amongst them there are some who only require encouragement to become themselves useful scientific workers. This is true of no department of science so completely as it is of Meteorology; for the weather is almost the only subject on which people of the most diverse opinions can exchange harmonious views or indulge in the luxury of unanimous reprobation. It may possibly happen that a promising amateur meteorologist is sometimes repelled by the dulness of the vast array of heavy columns of figures, the marshalling of which constitutes so large a part of our work. If so, it is merely because he has not learned to look beyond the figures to the facts which they represent. We do not get one statistical paper too many: on the contrary, we want more of them, and we want more complete and more scientific discussion of all the figures that can be brought together. How then can we justify the introduction of what is avowedly and of set purpose a popular lecture into the proceedings of a scientific Society, the main purpose of which is the analysis of exact data?

The answer to this question is that by dwelling upon the general results which have already been obtained, and which can therefore be

described in popular language, we can best call attention to the value of the laborious researches which are still necessary to establish general truths; and perhaps by this means we can also gain the assistance or support of new recruits. Dealing as we meteorologists do with air, a medium invisible and almost intangible, the discovery of the existence of which was a feat of human reason almost equal to that of the planetary nature of the Earth, it is inevitable that we have little to show, little to take the eye. Our observations are made mainly by means of instruments, and whether we handle figures representing pressure, temperature, humidity, wind-force, precipitation, or any other element of meteorology, the rows of figures in themselves are as uninteresting, and perhaps not so stimulating to the untrained imagination, as the entries in a merchant's ledger.

In other sciences—physics, chemistry, geology, geography—there is something to see; and things seen are what attract the fresh mind and lead it on to the abstruser studies which involve quantities rather than qualities. Probably most of us feel that there is something particularly attractive in the study of clouds, lightning-flashes, sunshine, and a few may even cherish a certain subdued interest in rain, snow, and hail. We can feel the change of temperature, and most people realise the interest of warmth and cold; but the changes of pressure on which the whole of meteorology rests are imperceptible except to the imagination, and must be inferred from the movements of the barometer or from their effects in changing the force or direction of the wind. When we consider not the phenomena of pure meteorology but the effects they produce, we enter on the part of our science which is of the greatest general interest, and it is from this side that I propose to speak of Climate this evening.

Climatology is as much a branch of Geography as of Meteorology, in fact more, for it not only deals with the distribution of atmospheric conditions over the Earth's surface, which is a geographical question in itself, but all the varieties of climate that give individuality to different countries are produced by the disturbing or controlling influence of land-forms. It was while studying the influence of land-forms on every kind of geographical distribution that I was struck by the far-reaching interest of the effects of climate; and now I intend to deal with the visible effects of climate, such as attract attention and arouse inquiry as to their causes. The observation of visible phenomena is most likely to bring in recruits to the study of Meteorology, and it keeps fresh in the minds of the devotees of the science the fact which we are too apt to lose sight of, that figures are important only in so far as they represent real existing things.

Visible effects can be photographed, and therefore these remarks will be illustrated by showing on the screen photographs which I have taken on various holidays in many countries, reinforced by others obtained from friends. But perhaps it would be more correct to say that I hope to give a connected explanation of the series of photographs, the existence of which suggested the subject of this lecture. Before getting to the main subject we must bestow a few prefatory thoughts on the principles of scientific photography, and on some of the wider bearings of climatology.

There is probably no department of art more conducive to dishonesty than photography; and some specimens of dishonest photographs now

shown should serve as a special warning to amateur photographers. The first warning is conveyed in an illustration published in a missionary magazine "after a photograph," although the incident shown in it is one that never could have been photographed at all. Such dishonesty is fortunately rare, but it should be unknown. The second is a beautiful picture, the beauty mainly lent by a magnificent cloud which was added by the mechanical photographer who made the slide as "a pleasing background." This is a common trick, but very improper. I remember a book describing a tour in the Mediterranean, illustrated by the author's photographs, in which he stated that the sky had been cloudless throughout. The eminent and popular firm who reproduced the pictures, however, inserted into each a background of homely English cumulus and stratus to fill up the ugly void. If scientific photographs are taken at all, they must be honest through and through: the natural sky alone can

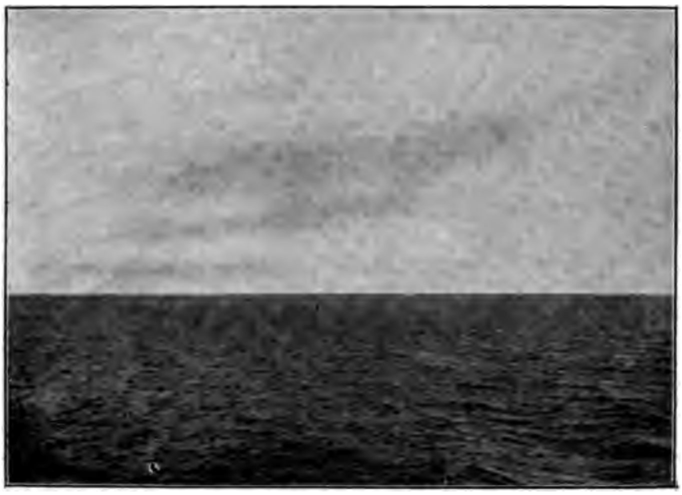

Fig. 1.—Steamer Smoke simulating Stratus Cloud.

be tolerated in any picture for scientific use. Passing by such crude temptations to scientific crime, we come to the difficulty which may beset an honest worker in recognising the true nature of a particular phenomenon. Care must be taken not to be misled by appearances whose origin is different from what we suppose. Sparks from the funnel of a steamer on a very dark night were, to my personal knowledge, hailed in all sincerity as a group of the missing Leonids; and a professor of astronomy is reported once to have taken a lighthouse for Jupiter. A photograph (Fig. 1) is shown which can hardly be distinguished from a typical stratus cloud, yet it consists merely of wreaths of steamer smoke on a dead-calm, cloudless summer day. Another phenomenon, apparently meteorological, is the fine rainbow over Niagara Falls, the photograph of which (Fig. 2) was also taken on a cloudless day, although the raised umbrella in the foreground shows how effectively the fine spray from the Falls simulates rain—perhaps it is what the biologists would term a "mimetic resemblance."

So much for the warning preface.

We may define "Climate" as the normal or average condition of meteorological phenomena at a given place, in which case "Weather" would have to be defined as the temporary disturbances of climate which occur from day to day. On the other hand, we may consider "Weather" first, and define it as the condition of the atmosphere at any moment with regard to wind, warmth, cloud, electricity, and precipitation; then "Climate" might fairly be called the average weather of a place. The latter is the practical way of approaching the question; the former is the theoretical. Suppose that the Earth had a smooth and uniform surface, all sea, or all land of the same kind. Then the atmospheric conditions would depend solely on the way in which the sun's rays fell at the different periods of the year, and the climates would be ideally simple,

FIG. 2.—Niagara Spray and Rainbow.

resulting from the form and the astronomical movements of the planet. Given the latitude of a place, we could tell by a direct calculation from the obliquity of the ecliptic and the position of the Earth in its orbit what would be the atmospheric conditions for any particular day in the year, and this would hold good for the same day in every other year. There would be no room for a science of meteorology; there would hardly be any weather, since, except for such disturbing causes as the moon and the planets, or the varying intensity which solar activity might exert, there would be nothing to produce any change. Such an ideal distribution of climate is the basis of that which we suffer or enjoy; but the simplicity is driven out of it by the difference in the capacities for heat of land and water, and the varieties of the form of the land. The symmetrical climate-belts of the frigid, temperate, and torrid zones only appear in odd patches where a vast stretch of sea such as the Pacific or the Southern Ocean presents some approach to the uniform conditions we have imagined. In reality, we find that the more rapid heating and cooling of land than of sea intensifies the seasonal changes in the interior

of the great continents, making the summers hotter and the winters colder. Minor centres for the heating and cooling of air are thus created, and the zones of winds as well as of temperature are distorted. The sea winds drawn in towards the land in summer, the land winds driven out towards the sea in winter, carry the climates of the ocean or of the continent in succession across the coastal belts. The incidence of precipitation, whether in the form of rain or snow, is complicated by the variations in the form and elevation of the land and the run of the mountain ranges; and we find that the actual distribution of rainfall results largely from the influence of land-forms upon prevailing winds. It is true that in the equatorial region, where the heat is always great and the hot, vapour-laden air is always ascending and cooling, there is a belt of maximum rainfall over sea as well as over land, almost right round the world; but elsewhere, in the centres of the continents, protected by bordering mountain systems from vapour-laden winds, evaporation is usually in excess of precipitation, and great desert zones result north and south of the equator. Further north and further south than these the atmospheric eddies known as cyclones complicate the arrangement of climate still more; and the normal effect of seasonal change is almost lost sight of in the less easily classified varieties of weather. But even when the climate is only an unassorted collection of storms and intervening calms the powerful influence of land-forms on the moving air makes itself felt. In the British Islands, for instance, the contrast between the oceanic and the continental side is very clearly marked, and much intensified by the fact that the oceanic side is also the mountainous side, and the continental side the plain. And, to go into greater detail, even on so moderate a ridge as the South Downs we find that the distribution of rainfall is in delicate adjustment with the prevailing wind and the height, slope, and direction of the line of hills.

To sum up this part of the subject, we may say that the astronomical partition of solar warmth over the Earth's surface, with its simple arrangement of prevailing winds and belts of drought and flood, is redistributed by the geographical conditions of the Earth's crust, and so modified as to provide in every place a climate due to a play of influences too complicated for the theorist to lay down from *a priori* reasoning. That is the reason why the long-continued observations of thousands of people for scores of years are necessary in order to determine what the true climate of a place is, and why we meteorologists must wade or swim to our conclusions through an almost overwhelming sea of figures.

But the whole world we know is knit together, every part of it affecting every other. Configuration redistributes solar heat and makes our climate; climate rules supreme over plant life and animal life; and all together conspire, according as the various elements are kindly or unkindly mixed, to render certain parts of the world pleasant, tolerable, or deplorable as the abode of man.

After this long introduction, it is time to consider the visible effects of climate. The effects of weather ought to be excluded from consideration, except in so far as the type of weather is characteristic of a special climate. Here I cannot be so systematic as is desirable, because I am limited by the illustrations, and they were picked up here and there at odd times with never a thought of bringing them together for such a

purpose as the present. The main grouping will be purely popular, in a sense almost pre-scientific, for it nearly goes back to the old "principles" of the alchemists, who classified everything according as it was hot, cold, moist, or dry. We shall pass in review some of the peculiarities of climates in which heat, cold, wind, and rain respectively predominate, showing how the varying conditions of climate created by the greater land-forms are responded to by the various adjustments of minor land-forms and of plants, and how they are taken advantage of by man.

The usual cause of extreme heat or cold is unrestricted radiation, which implies a clear atmosphere and almost always low humidity. The

FIG. 3.—Burnt Forest on the Slopes of Mount Macdonald, Canadian Rockies.

result is that the summers of relatively dry countries in the temperate zone are very hot; and, except Siberia, there is no better example of this than Canada, where the extreme dryness often leads to forest fires of vast extent and destructiveness. Nothing is more dismal than to pass in the train through hundreds of miles of burnt forest, the great old stems still standing although the branches have been burnt off, while the young undergrowth struggles slowly to renew the wood. The photographs (*e.g.* Figs. 3 and 16) shown are fairly typical of the state of matters where damage from railway sparks is a real national danger. Where, in the heart of a continent, the rainfall is less than the minimum necessary to enable trees to grow permanently, we see, as on the Canadian prairies, the typical steppe vegetation—bare plains of grass and low shrubs, with no trees except along the rare rivers or in irrigated spots. Trees grow well enough

if planted and watered; their absence is an effect not of bad soil but of extreme climate. One step more leads us to the true arid desert, where there is not enough rain even to permit the growth of grass, and only specially modified plants can struggle in sparse clumps through the sand.

Just as unrestricted radiation during summer tends to scorch and dry up the land, it tends, by promoting evaporation, to lower the level of standing water. When a very dry season, like the summer of 1894, occurs in this country, the lakes shrink rapidly, as is neatly shown in the view of Friar's Crag at Derwentwater, where records of the lowest level have been preserved for a century. Each continent holds one or more salt lakes in its arid centre, where evaporation keeps the level of the water which is poured in by rivers so low that the lake is never able to fill up its hollow and consequently cannot overflow to the sea.

Solar heat is utilised in cloudless countries in many ways. In the

FIG. 4.—Stunted Forest near Bodö, in Arctic Norway.

salt-pans of the Mediterranean, sea-water is admitted in shallow layers and evaporated economically by the sun to leave a bed of salt. The heliograph is well known to us in our foreign wars, and in the Algerian Sahara it has for years served as a wireless telegraph in regular employment for the purposes of peace. In that enterprising portion of France across the water the concentration of the sun's rays by reflectors has even been used to generate steam for small engines, as Archimedes centuries before is said to have used them to burn the ships of a hostile fleet. Our climate debars us from this meteorological method of national defence. It makes it difficult for us also to understand the immense value of shade in cloudless lands, or to appreciate the purpose of the narrow streets and overarched footways of many Italian towns.

Cold—if one may use that convenient expression for low temperature—is more familiar to us; but not the extreme dry cold of the Arctic regions or the centres of the continents. In northern Norway one sees beautiful examples of the stunting effect of cold on vegetation (Figs. 4

and 5), and on the outer islands, far within the Arctic Circle, still more interesting instances of the power of genial sea-winds to temper the continental rigour; but the climate of that region has recently been dealt

Fig. 5.—Stony Desert on the top of the North Cape in Norway.

with very fully by our late President, Dr. C. Theodore Williams. Snow, a drug in the climatological market of the northern continents, is a rarity in Australia, where few mountains are high enough to allow it to

Fig. 6.—Valley in British Columbia blocked by Tree Trunks carried down by an avalanche.

form, and where it is regarded with a sentimental interest as one of the links with Home.

On the slopes of the higher mountains of the world curious local

climates are created by the tongues of ice creeping down the valleys from the great permanent snow-fields of the summits. In melting, these glaciers form streams which are mere trickling brooks in the morning, but swell as the summer day advances until they have become raging torrents by the evening, when the melting-power of the sun has had time to accomplish its full day's work. In such regions also avalanches at certain seasons occur so frequently as almost to establish a claim to be classed as climatic factors rather than catastrophes. Many evidences of the destructive power of snow-slides (Fig. 6) may be seen while traversing the Rocky Mountains, when the train emerges to daylight between two of the protective snow-sheds constructed for miles along the mountain-sides. The contrast between the dry continental and the moist oceanic slope of the mountains is beautifully brought out by the sudden appearance of snow and snow-sheds on crossing the water-shed from the east.

FIG. 7.—Limone, on the Garda Lake, showing the Lemon Gardens.

The plan of the dwellings in cold countries is dictated by the climate, whether we consider the Eskimo's ice-hut, or the carefully caulked log-cabin of the Canadian prospector, or the elaborate double-windowed and stove-heated houses of all continental countries. So too, where cold is rare but occasional, we sometimes find elaborate measures taken to minimise its bad effects. Every year fresh groups of tourists are struck with the densely crowded cemeteries that appear along the shore of the Garda Lake, and require to be told that the innumerable white obelisks, at Limone, for instance, are only the supports for temporary roofs to be placed over the lemon gardens on a threatening of frost (Fig. 7). Artificial smoke has been tried in America to check radiation from the ground and avert the serious consequences to crops of a threatened summer frost.

Amongst the effects of cold, few are more interesting than those which bear witness to the climate of a former period. Geology deals with many such instances, but we shall refer to only one. The sign-manual of ice upon the rocks it polished when the Glacial Period was at its full is

absolutely unmistakable, whether we find it in our own islands, on the coast of Sweden, or in the remotest of the Canadian lakes, as the illustrations exhibited very clearly show.

FIG. 8.—Tree warped by Prevailing Wind.
(Photograph by Dr. A. Hardwick of Newquay, Cornwall.)

In its climatic or uniform character Wind is less striking than when it appears with exceptional force in regions which are normally quiet. In this case I yield to temptation and show a few examples of the excep-

FIG. 9.—Trees on windward side of cliff near Brastad, Bohuslän, Sweden.

tional power of wind in demolishing structures and uprooting trees. The steady action of prevailing winds, though less conspicuous, is distinct enough when we know how to look for it, whether it be the chiselling of

the rocks by the sand-blast in the islands of the Southern Ocean where the "Roaring Forties" blow, or the torturing of trees into fantastic shapes as exemplified round our own coasts (Fig. 8). One particularly interesting case of the action of a strong prevailing sea-wind on trees I photographed last summer in western Sweden (Fig. 9), where a line of lofty cliffs crossed a desolate, wind-swept moorland which was absolutely treeless on account of the strength of the blast. On the windward side of the cliff, where the wind blowing over the surface was abruptly checked and thrown upward by the rock, a group of fine birches grew, their trunks flattened

FIG. 10.—Captain Baden-Powell raised by a train of five Kites at Ipswich, 1895.

against the granite and moulded to its surface, while their topmost twigs were cut off sharply where the wind recovered its strength in sweeping unimpeded over the summit.

The value of the wind for practical purposes depends much on its freedom from interruption by inequalities of land. At sea, where there is nothing to obstruct it, the sailing ship, certainly at least the sailing boat, will never pass out of use; but on shore, where every accident of the superficial relief checks and breaks its force, wind-power can only be fully utilised on open hill summits or wide plains across which it sweeps unimpeded as over the sea. Sailing on land, although only a sport in Europe and America, is a time-honoured means of transport in China. Wind motors perched on tall steel masts can utilise wind-power more effectively than the old type of windmill near the surface of the ground.

A very interesting application of wind-power is the development of the kite and its adaptation not only for raising recording meteorological instruments into the upper atmosphere, but for raising a man for scouting purposes in warfare (Fig. 10).

The weighting with stones of the broad-eaved roofs of mountain cottages in the Alps (Fig. 11) and the Himalayas is a precaution born of the wild gusts which rush down the gullies of mountainous lands.

Lastly, we have to consider the climatic effects of precipitation. Few places lie above the clouds; still, on many lofty mountains there is a cloud-line nearly as distinct as the snow-line, though shifting its position with the time of day as well as with the time of year. A belt of mist runs along the mountain slope, and the climber has to pass from the sunlight below to the sunlight above through a wet zone in which nothing is to

Fig. 11.—Typical Alpine Chalet in the Zillerthal.

be seen. In cold mountainous countries facing a warm sea the occurrence of mist and fog is so frequent as to form a climatic condition rather than a mere effect of weather as with us, and the long bars of mist rising from the surface of the sea are one of the characteristics of Norway (Fig. 12). In high latitudes in the south, fogs are so regular in their appearance that a clear day is almost a rarity. Lands known to exist have been hidden so thoroughly from this cause that Bouvet Island in the Southern Ocean, which was discovered in 1739 and sighted once or twice by chance whalers in subsequent years, although searched for by some of our greatest explorers, was never found when looked for until an expedition on the German steamer *Valdivia* hunted it down and photographed it during a momentary break of the cloud-cap two years ago.

The fairy-like beauty of some of the forms of precipitation in cold climates, where the vapour condenses directly into the solid crystal, is revealed to us in occasional glimpses as a rare shower of "snow-stars" or a more frequent exhibition of frost-ferns. But our usual form of precipitation is not fairy-like. Without going so far as a certain London morning

paper and characterising rain as "that most undesirable element of our climate," it is not difficult to recognise the prosaic features of a wet day. On the effects of rain we cannot linger long, though very much might

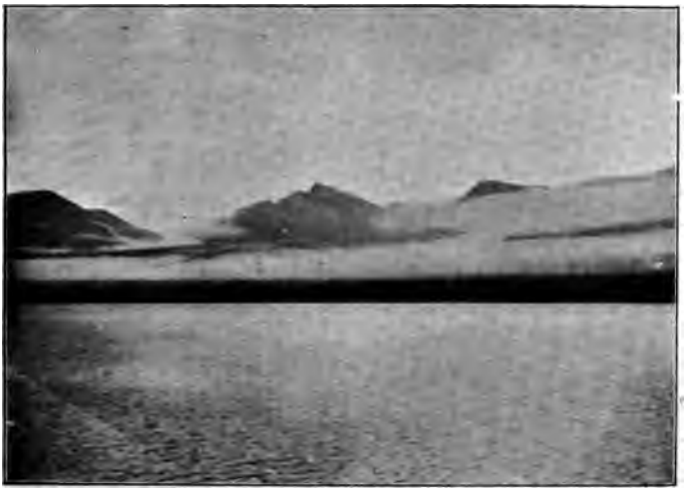

FIG. 12.—Mist Bars on the Coast of South-western Norway.

be said about floods, water-spouts, and other exceptional manifestations. Much also might be said as to the smiling verdure of the rainiest parts of our own islands, and the exquisite beauty of a stray fine day when the sun

FIG. 13.—Hay-drying Stakes in the Zillerthal, North Tyrol.

bursts through the rain-clouds. For if a dry climate is sometimes broken by storms, a rainy climate is often brightened by the most superb weather we ever experience. Every form of atmospheric agency stamps its own

peculiar mark on the land which it beats upon and fashions into shape. Much depends of course upon the material it has to work with; and nothing equals in grotesqueness the handiwork of rain on beds of stony clay. Whether it be only the guttering of the sides of a railway cutting, or the fantastic carving of a thick bed of boulder clay into earth pillars, or the weathering of soluble limestone or intractable granite, rain does its work in a way of its own. Although the farmer grumbles when rain is lacking during the period of growth, he grumbles more when it obtrudes its unwelcome presence in harvest-time or at haymaking, and many ingenious contrivances are in use in rainy countries to take the fullest advantage of every dry interval. The familiar piling of sheaves on the harvest-field is not enough to secure dryness in a land of sudden and frequent showers.

FIG. 14.—Frame for drying Crops in the Ampezzo Valley, South Tyrol.

In the Alpine valleys of northern Tyrol the hay or other crop is dried on stakes, branched like a hat-stand, on which the wisps are draped well above the ground (Fig. 13). Driving past the hayfields of the Zillerthal in the twilight we see them as if occupied by a great body of soldiers, standing rigidly at attention. In the southern valleys of Tyrol, the Italian peasants rear enormous frames in their farmyards, comparable to nothing so much as the erections on the roof of a telephone exchange; and on these the crops to be dried are hung for the wind to whistle through them (Fig 14). In the damp islands and coast strip of Norway, hurdles like ordinary fencing are erected in the fields, and the grass when cut is hung upon these to dry like linen on a clothes-screen (Fig. 15). It is curious that the farmers of the wet western districts of our own country employ no such devices to make the most of the dry intervals in showery weather; but in newer lands, where people have to exert themselves to the utmost or starve, new ideas are eagerly carried out. In passing along the Canadian Pacific line, near Albert Canyon, I took a snap-shot of a hayfield while the train was at full speed (only 10 miles an hour, but 60 judging by the jolting), and secured a picture of a set of regular Norwegian

hurdles clothed with British Columbian hay (Fig. 16). The farm, the conductor of the train said, belonged to a Scandinavian immigrant.

FIG. 15.—Hay-drying Hurdles at Bodö, Norway.

With us, one of the chief essentials of a house is to keep the wet out, and care is taken to protect the walls as much as possible from the inroads of rain, though this is rarely done so thoroughly as in the quaint

FIG. 16.—Hay-drying Fences at Albert Canyon, B.C., with Burnt Forest in background.

thatched cottages of the south-eastern coast of England, where the thatch is often carried down almost to the ground over the windward gable, the house being equipped with a veritable sou'-wester. In Russia and other

northern countries it is almost comical to see how every wooden structure has its roof; even a stake driven into the bed of a river for mooring boats to, bears its pointed cap of thatch to prevent rain from soaking into the grain of the wood and destroying the whole when it freezes in winter. No one can help being struck also in St. Petersburg by the enormous size and unusual number of the gutters and pipes for conducting water from the roofs of the buildings, yet the rainfall in St. Petersburg is much smaller than it is with us. The solution of the puzzle is to be found in the regularity of the snowfall, which accumulates on the roofs during winter, helping to keep the houses from becoming excessively cold, and then in the first warm spring days suddenly melts and pours in cataracts down the openings which experience has provided.

These illustrations have been chosen almost at haphazard, and they present only a series of suggestions which might be followed out by any one interested in the subject who is willing to learn that the commonest things are the most important for the purpose of getting a true impression of the real character of a new climate, a new country, or a new people.

NOTE.—The sixteen photographs reproduced in illustration of this abstract are selected from over sixty lantern-slides exhibited during the lecture.

Lightning Research Committee.—This Committee, which has been organised by the Royal Institute of British Architects, and the Surveyors' Institution, has issued the following notice:—

"Having regard to the risk of damage by lightning to which our most valuable and historical buildings and monuments are liable, and against which existing systems of protection do not appear to provide sufficient safeguards, the above Committee has been appointed for the purpose of obtaining trustworthy information on future disasters from lightning, with a view to improving, if possible, the means of protection.

"In pursuance of this inquiry, the Committee seek the co-operation of competent observers in all parts of Great Britain, in order to obtain accurate details, noted on the spot, of the effect of lightning-strokes on buildings, whether fitted with lighting-rods or not, and as full information as possible on the various matters indicated in the Schedule of Questions prepared for the guidance of observers.

"Persons willing to assist the Committee by acting as observers are requested to be good enough to communicate with "The Secretary, Lightning Research Committee, R.I.B.A., 9 Conduit Street, W.," who will at once supply them with copies of the Schedule above mentioned."

The Members of the Lightning Research Committee are:—

JOHN SLATER, B.A., F.R.I.B.A., *Chairman.*
Major-General E. R. FESTING, C.B., F.R.S.
J. GAVEY, M.Inst.C.E.
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ARTHUR VERNON, F.S.I.
KILLINGWORTH HEDGES, M.Inst.C.E., *Hon. Secretary.*
G. NORTHOVER, *Secretary.*

Mr. Shaw is the representative of the Royal Meteorological Society.

THE SPECIAL CHARACTERISTICS OF THE WEATHER OF MARCH 1901.

By WILLIAM MARRIOTT, F.R.Met.Soc.

[Read April 17, 1901.]

It is not often that *The Times* refers to the weather in a leading article, but on March 30 reference was made to it as follows:—

"We do not profess to know to what extent the hypothesis will commend itself to astronomers or to meteorologists, but an impression has come to prevail, among the general public, that something remarkable must have happened to the axis of the earth, in order to account for a departure from the ordinary course of seasons, through which January would appear to have lost its way amid the courses of the stars, and to have returned to us, in full vigour and intensity, at the very period when, in accordance with all tradition, it is the special duty of March to 'be going out like a lamb.' The fact that the Grand National was run yesterday at Liverpool in a snowstorm, although it serves to accentuate the unusual character of the existing conditions, is not without precedent, for the same thing has happened, two months later in the year, with the Derby. But as one swallow does not make a summer, so one snowstorm did not make a winter; and it is the long continuance of cold and inclemency which constitutes the peculiarity of the present season."

Fig. 1.

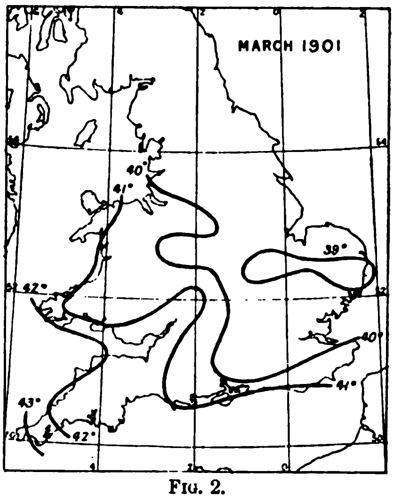

Fig. 2.

As a rule, the general meteorological features of the month of March are very irregular, but its main character is that of boisterousness and cold—more particularly during the first fortnight, especially if accompanied by bitterly cold Easterly winds. An occasional gale may occur at any time. Sometimes a strong North-east wind is prevalent, which, when it lasts many days, induces a rapid evaporation from the soil, respecting which we have the following old proverbs:—

"March dust is worth a king's ransom."
"A dry and cold March never begs its bread."
"March, black ram,
Comes in like a lion; goes out like a lamb."

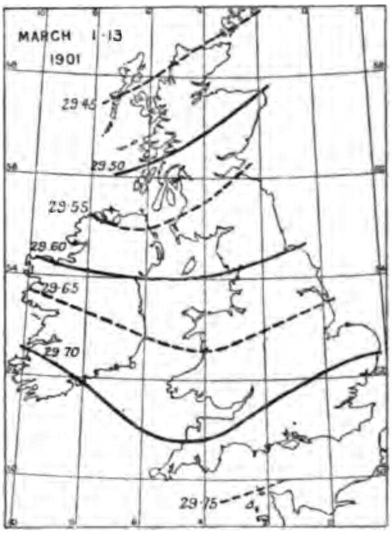

FIG. 3.

FIG. 4.

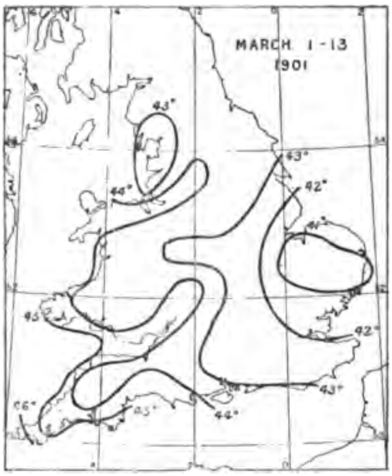

FIG. 5.

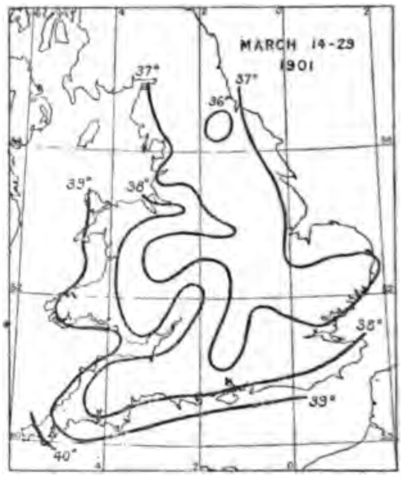

FIG. 6.

March, however, is occasionally cold nearly throughout; this was particularly the case in the years 1845, 1855, 1865, 1883, and 1892. Snowstorms occur occasionally which give a very wintry appearance to the landscape; but as the sun begins at this time to have more power, the snow seldom remains long upon the ground.

"When Februeer is come and gone,
The snow lays upon a hot stone."

On reference to the charts of mean atmospheric pressure over the British Isles for the month of March, it will be seen that the isobars run nearly east and west; the pressure being higher to the south and lower to the north.

The chart of mean pressure for March 1901 (Fig. 1) shows that the pressure was highest in the south-west, and lowest in the north; the difference between the isobars, however, being but slight.

From an examination of the charts of mean temperature over the British Isles for the month of March it is found that the isothermal lines run from west-north-west to east-south-east, and that the temperature falls from 47° in the south-west to 39° in the Shetlands.

The mean temperature for March 1901 over England and Wales is shown in Fig. 2, from which it will be seen that the highest temperature occurred in the extreme south-west, and that it diminished towards the north-east. The temperature for the month was about 3° below the average.

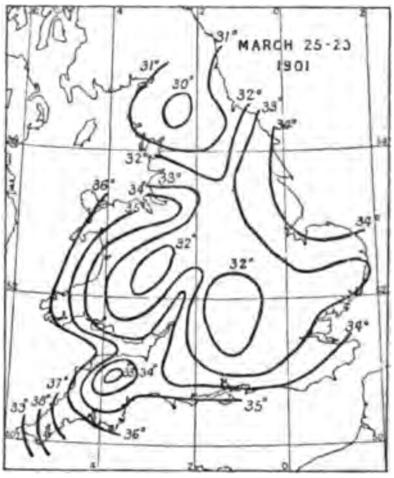

FIG. 7.

FIG. 8.

The weather from the 1st to the 13th was comparatively mild, the temperature being a little above the average. The winds were mostly from the South-west and West, and strong in force; and thunderstorms were of frequent occurrence. A change set in on the 14th, completely reversing the former conditions, causing low temperatures and keen North-easterly winds.

The marked contrast between these two periods is shown by the isobaric charts, Figs. 3 and 4, and by the isothermal charts, Figs. 5 and 6.

The last two days of the month were much warmer, although still slightly below the average.

From the 25th to the 29th the cold was more intense, the temperature being very low, and the wind particularly keen and dry, Fig. 7. The temperature during this period was more than 10° below the average. From the *Weekly Weather Report* it appears that, for the week ending March 30th, the temperature over Scotland was 10° below the average, over the greater part of England and Wales 9°, and over Ireland 8°, Fig. 8.

TABLE I.—Mean Maximum, Mean Minimum, and Mean Temperatures for the month of March 1901; and also for the Three Periods (1) 1st to 13th; (2) 14th to 29th; and (3) 25th to 29th.

Station.	Month of March.			March 1-13.			March 14-29.			March 25-29.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
England, N.E.	°	°	°	°	°	°	°	°	°	°	°	°
Rothbury	44.2	32.4	38.3	48.6	35.4	42.0	40.3	30.2	35.3	36.6	21.8	29.2
Ushaw	44.4	31.9	38.2	49.2	35.1	42.2	40.3	29.5	34.9	36.1	22.1	29.1
Rounton	45.0	32.3	38.7	49.2	35.9	42.6	41.2	29.2	35.2	37.5	21.2	29.4
Scarborough	44.6	35.9	40.3	48.1	38.5	43.3	42.0	33.9	38.0	39.1	28.7	33.9
England, E.												
Hillington	44.7	33.0	38.9	47.5	33.5	40.5	41.6	32.1	36.9	40.1	27.4	33.8
Brundall	44.4	33.9	39.2	47.8	35.1	41.5	41.0	33.0	37.0	39.3	27.5	33.4
Lowestoft	42.4	34.7	38.6	45.2	35.9	40.6	39.9	33.2	36.6	37.9	26.8	32.4
Southwold	42.8	34.5	38.7	45.6	35.8	40.7	40.5	33.1	36.8	38.7	26.2	32.5
Wryde	46.1	31.4	38.8	48.6	32.7	40.7	43.0	29.9	36.5	41.2	23.6	32.4
Ely	45.5	32.9	39.2	48.6	34.3	41.5	42.5	31.3	36.9	41.3	25.8	33.6
Thurlow	43.7	31.6	37.7	46.5	33.1	39.8	40.9	30.1	35.5	38.2	24.7	31.5
Halstead	44.7	32.6	38.7	47.4	33.9	40.7	41.9	31.0	36.5	39.8	25.7	32.8
Chelmsford	44.7	32.7	38.7	47.9	34.1	41.0	41.5	31.0	36.3	39.1	25.0	32.1
Bennington	44.0	31.8	37.9	47.0	33.3	40.2	41.1	29.9	35.5	38.9	24.2	31.6
Midland Co.												
Harrogate	43.7	32.2	38.0	47.8	35.5	41.7	40.1	29.5	34.8	37.1	22.8	30.0
Wakefield	45.4	34.0	39.7	48.9	37.9	43.4	42.1	30.9	36.5	39.5	26.3	32.9
Hodsock	46.7	32.6	39.7	50.1	35.7	42.9	43.3	29.7	36.5	41.1	24.8	33.0
Strelley	44.7	32.3	38.5	48.0	35.1	41.6	41.5	29.7	35.6	38.9	23.5	31.2
Buxton	41.3	30.8	36.1	44.1	34.3	39.2	38.6	27.5	33.1	36.0	21.6	28.8
Belper	44.3	33.0	38.7	48.0	36.2	42.1	40.8	30.1	35.5	38.6	24.6	31.6
Cheadle	43.6	32.2	37.9	46.7	35.1	40.9	40.5	29.7	35.1	37.2	23.6	30.4
Derby	45.6	33.7	39.7	49.0	36.9	43.0	42.2	30.9	36.6	40.0	24.6	32.3
Roden	44.8	32.8	38.8	47.9	35.5	41.7	41.7	30.3	36.0	38.5	24.5	31.5
Churchstoke	44.6	32.4	38.5	48.0	35.8	41.9	41.2	29.4	35.3	37.8	22.0	29.9
Malvern	45.1	34.6	39.9	48.3	37.7	43.0	42.0	31.9	37.0	39.6	27.2	33.4
Belmont	46.0	34.0	40.0	49.7	36.7	43.2	42.4	31.3	36.9	39.6	25.3	32.5
Ross	46.6	34.5	40.6	50.1	36.7	43.4	43.3	32.1	37.7	40.6	26.0	33.3
Cheltenham	46.4	32.7	39.6	49.5	35.5	42.5	43.1	29.6	36.4	40.1	22.1	31.1
Ravensthorpe	43.9	32.1	38.0	47.1	34.0	40.6	40.4	30.3	35.4	38.2	23.7	31.0
Berkhamsted	44.9	32.1	38.5	47.9	34.2	41.1	42.0	29.8	35.9	39.1	23.8	31.5
England, S.												
Regent's Park	44.9	34.2	39.6	47.9	36.0	42.0	41.9	32.5	37.2	39.1	26.8	33.0
Old Street, E.C.	45.3	35.8	40.6	48.1	37.8	43.0	42.5	33.9	38.2	39.9	28.8	34.4
Greenwich	45.0	34.1	39.6	48.0	35.5	41.8	42.1	32.6	37.4	39.8	26.6	33.2
Kew	45.2	35.0	40.1	48.3	36.4	42.4	42.0	33.5	37.8	39.0	27.6	33.3
Norwood	45.0	34.0	39.5	48.2	35.6	41.9	41.8	31.9	36.9	39.7	25.9	32.8
Addington	42.7	33.0	37.9	45.9	35.0	40.5	39.6	31.2	35.4	36.8	25.4	31.1
Beddington	45.0	33.3	39.2	48.5	34.5	41.5	41.8	31.8	36.8	39.6	25.3	32.5
Worcester Park	45.3	33.8	39.6	48.1	35.6	41.9	42.4	32.0	37.2	39.5	25.7	32.6
Shaftesbury	43.7	33.1	38.4	47.2	36.1	41.7	40.2	30.2	35.2	38.1	24.9	31.5
Marlborough	45.0	32.7	38.9	48.0	35.0	41.5	42.0	30.3	36.2	40.2	23.3	31.8
Winterslow	45.0	31.9	38.5	48.1	34.6	41.4	41.9	29.2	35.6	39.8	22.3	31.1
Harestock	45.5	32.6	39.1	49.1	34.7	41.9	42.1	30.2	36.2	40.2	23.5	31.9
Swarraton	44.5	32.7	38.6	47.5	35.1	41.3	41.6	30.2	35.9	38.6	23.1	30.9
Grayshott	43.0	32.1	37.6	45.8	34.5	40.2	40.2	29.7	35.0	37.7	23.5	30.6
Cranleigh	45.2	33.2	39.2	48.7	34.9	41.8	42.1	31.6	36.9	39.7	25.1	32.4
Tunbridge Wells	43.3	33.3	38.3	46.6	35.3	41.0	40.1	31.3	35.7	37.4	25.0	31.2
Tenterden	44.2	34.5	39.4	47.2	36.7	42.0	41.1	32.5	36.8	38.3	25.6	32.0

TABLE I.—MEAN MAXIMUM, MEAN MINIMUM, AND MEAN TEMPERATURES—*Continued.*

Station.	Month of March.			March 1-13.			March 14-29.			March 25-29.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
	°	°	°	°	°	°	°	°	°	°	°	°
Margate	43·8	36·0	39·9	46·7	37·7	42·2	40·8	34·8	37·8	38·8	29·7	34·3
Folkestone	43·5	36·2	39·9	46·1	38·2	42·2	40·7	34·8	37·8	38·3	29·6	34·0
Bexhill	44·7	34·8	39·8	47·4	37·0	42·2	42·3	32·7	37·5	39·2	26·1	32·7
Eastbourne	44·9	37·0	41·0	47·3	39·3	43·3	42·4	34·9	38·7	40·0	29·4	34·7
Brighton	46·2	36·3	41·3	48·0	38·8	43·4	44·6	34·0	39·3	41·9	27·9	34·9
Worthing	45·0	35·5	40·3	47·3	37·9	42·6	42·9	33·3	38·1	41·0	26·7	33·9
Bognor	45·2	35·9	40·6	47·4	38·3	42·9	43·1	33·5	38·3	40·5	27·3	33·9
Portsmouth	45·9	36·0	41·0	48·8	38·5	43·7	43·3	33·5	38·4	40·4	27·7	34·1
Ventnor	45·6	36·4	41·0	48·1	39·0	43·6	43·3	33·8	38·6	42·1	29·0	35·6
Bournemouth	45·9	35·2	40·6	48·8	38·1	43·5	43·0	32·2	37·6	41·3	26·6	34·0
Weymouth	45·5	36·4	41·0	48·4	39·4	43·9	42·6	33·5	38·1	41·4	28·8	35·1
ENGLAND, N.W.												
Scaleby	45·7	32·7	39·2	48·9	36·2	42·6	43·2	29·8	36·5	40·0	20·8	30·4
Appleby	44·4	31·9	38·2	48·3	35·9	42·1	41·0	28·6	34·8	36·8	19·5	28·2
Seathwaite	43·7	32·7	38·2	46·5	36·7	41·6	41·8	29·5	35·7	36·9	22·1	29·5
Bolton	43·8	33·4	38·6	46·9	36·8	41·9	40·9	30·7	35·8	37·5	24·2	30·9
Northwich	46·9	33·6	40·3	49·9	37·1	43·5	43·9	30·8	37·4	41·9	25·0	33·5
Chester	46·5	34·6	40·6	49·4	37·9	43·7	43·6	31·8	37·7	41·3	26·9	34·1
Blackpool	45·6	33·2	39·4	47·4	37·2	42·3	44·1	29·7	36·9	40·4	25·0	32·7
Southport	45·3	34·0	39·7	47·6	37·8	42·7	43·0	30·6	36·8	39·8	25·5	32·7
Hoylake	45·6	35·2	40·4	47·9	38·7	43·3	43·5	32·5	38·0	41·8	27·9	34·9
Llandudno	45·3	36·7	41·0	48·0	39·9	44·0	42·8	34·1	38·5	41·4	30·8	36·1
Llanerchymedd	46·1	...	...	49·1	38·0	43·6	43·5	...	...	41·5	...	...
Llanbedr	46·8	...	...	48·4	39·3	43·9	45·1	...	...	40·9	...	...
ENGLAND, S.W.												
Aberystwith	45·1	36·1	40·6	47·0	39·6	43·3	43·4	33·1	38·3	39·5	27·6	33·6
Gwernyfed Park	45·0	32·4	38·7	49·0	35·8	42·4	41·8	29·3	35·6	38·4	22·3	30·4
Haverfordwest	46·8	35·3	41·1	49·0	39·6	44·3	44·7	31·0	37·9	40·8	26·7	33·8
Rumney	46·5	34·6	40·6	49·8	37·6	43·7	43·1	31·8	37·5	40·7	25·3	33·0
Ilfracombe	45·9	38·6	42·3	48·2	41·6	44·9	43·5	36·0	39·8	41·2	32·8	37·0
Woolacombe	46·2	37·3	41·8	48·8	40·5	44·7	43·8	34·2	39·0	41·2	31·7	36·5
Bath	46·8	34·3	40·6	50·0	36·5	43·3	43·7	31·9	37·8	41·7	26·0	33·9
Ilton	47·3	35·2	41·3	50·8	38·7	44·8	43·8	31·9	37·9	42·0	27·4	34·7
Cullompton	47·1	33·8	40·5	50·9	37·0	44·0	43·4	30·7	37·1	41·8	24·9	33·4
Castle Hill	45·7	32·5	39·1	48·9	36·0	42·5	42·6	29·2	35·9	39·5	22·9	31·2
Buckfastleigh	46·6	34·9	40·8	50·0	38·8	44·4	43·3	31·1	37·2	43·8	24·9	34·4
Ashburton	46·2	34·8	40·5	50·6	38·4	44·5	42·0	31·7	36·9	39·8	28·6	34·2
Princetown	39·9	30·4	35·2	43·4	34·5	39·0	36·6	27·0	31·8	35·2	22·0	28·6
Whitchurch	44·2	33·5	38·9	47·2	36·8	42·0	41·2	30·2	35·7	39·8	24·3	32·1
Rousdon	44·8	33·7	39·3	48·1	36·8	42·5	41·7	30·5	36·1	40·4	26·0	33·2
Sidmouth	46·5	34·9	40·7	49·5	38·5	44·0	43·4	31·3	37·4	42·5	26·8	34·7
Torquay	46·7	36·8	41·8	50·4	40·1	45·3	43·4	33·7	38·6	43·6	27·6	35·6
Newquay	46·3	37·6	42·0	48·7	41·3	45·0	44·0	34·2	39·1	43·3	30·9	37·1
Falmouth	46·7	36·3	41·5	49·6	39·2	44·4	44·0	33·3	38·7	44·2	28·9	36·6
Penzance	48·1	38·5	43·3	50·8	40·9	45·9	45·3	36·1	40·7	45·6	32·9	39·3
IRELAND.												
Enniskillen	45·1	33·5	39·3	48·0	37·8	42·9	43·0	30·2	36·6	40·4	24·5	32·5
Ardgillan	46·3	34·6	40·5	49·1	37·1	43·1	43·8	32·8	38·3	39·5	25·2	32·4
Dublin	47·0	36·7	41·9	50·2	39·4	44·8	44·3	34·5	39·4	41·4	28·3	34·9
Cahir	47·6	32·7	40·2	49·0	35·5	42·3	46·0	30·2	38·1	44·1	27·2	35·7
CHANNEL IS.												
Guernsey	46·1	39·3	42·7	48·6	41·3	45·0	43·6	37·3	40·5	44·0	32·8	38·4

Table I. gives the mean maximum, the mean minimum, and the mean temperatures at the stations of the Royal Meteorological Society for the month of March 1901, and also for the three periods (1) 1st to 13th, (2) 14th to 29th, and (3) 25th to 29th.

The great dryness of the air will be seen from the low relative humidity for the day recorded at the Royal Observatory, Greenwich, viz.:

March 26	52 per cent.
,, 27	54 ,,
,, 28	67 ,,
,, 29	63 ,,

It appears that a relative humidity as low as 52 per cent for the day in the month of March has only been recorded once before during the last 54 years, viz. on March 1, 1886, and no two consecutive days have had such low relative humidity in March as the 26th and 27th of the present year.

The comparatively slight variability in the maximum and minimum temperatures during the month is shown by the following figures for the Royal Observatory, Greenwich:—

Maximum Temperature. Number of times between	Minimum Temperature. Number of times between
55°–50° = 6	45°–40° = 1
50°–45° = 6	40°–35° = 17
45°–40° = 15	35°–30° = 7
40°–35° = 4	30°–25° = 5
	25°–20° = 1
Highest temperature 54°·1	Lowest temperature 24°·2

From an examination of the U.S. *Pilot Chart of the North Atlantic Ocean* it appears that a number of depressions passed across the Atlantic in a north-easterly direction during the month of March 1901, and that their path was considerably to the west and north-west of the British Isles. This confirms the reports in the newspapers of the boisterous character of the weather over the North Atlantic.

The only depression shown on the *Chart* which passed across the British Isles travelled in the unusual direction of from north to south, the centre being over the north of Scotland on the 7th, near Paris on the 8th, and over the Gulf of Genoa on the 9th. It was apparently this depression which caused the so-called "red rain" in the south of Italy.

During the thunderstorms on Friday, March 1, two cases of damage by lightning occurred, viz.:—

1. About 4.15 p.m. the lightning struck the roof of Kea church (south of Truro) near the south-east angle of the tower, and split between sixty and seventy of the tiles to fragments. The tower, which has a lightning conductor, escaped injury.

2. The other case of damage by lightning occurred to the smack *Wayfarer*, of Brixham. The crew had been engaged in fishing in the Bristol Channel, when during the gale, about 9 o'clock, the jib tack chain on the bowsprit was struck by lightning. The chain was cut in two, and the electricity passing in board did a lot of injury to the starboard bow of the smack just underneath the vessel's number. The planks were started and she began to fill, and, after some hours, sank. The crew, who had taken to their small boat, after buffeting about in a

heavy sea four hours, were sighted by a steamer, and brought safely to Brixham.

During the hail and thunderstorms which passed over the south of England on the morning of Wednesday the 6th, the German church at Dalston, London, was struck by lightning and set on fire. The organ loft and choir gallery were burnt out, the organ being destroyed.

On March 20 a snowstorm occurred over the south of England, being heaviest in the southern portions of Devon and Cornwall. At Torquay the melted snow yielded 2·31 ins., and at Buckfastleigh 2·06 ins.

The following extract from the *Western Morning News* of March 26 will give some idea of the intensity of the snowfall on Dartmoor:—

"It is only on rare occasions in Devon that we meet with drifts of snow from 5 to 12 ft. high, and spread over such a vast extent of country. Several people have estimated that more snow fell last Wednesday and Thursday than during the blizzard of ten years ago. Certainly the wind was not so keen, though it may have equalled that of 1891 in velocity. The postmen had arduous work in traversing the trackless moors on their rounds. Up to Sunday night vehicular traffic from Yelverton could not be carried on. From Tavistock, travellers were a little more fortunate; though, when within a few hundred yards of Rundlestone, vehicles came to a full stop at an enormous drift athwart the road. The returning officer for the Parish Council election, and the undertaker with the coffin for the man found dead, were served in such a manner, and had perforce to tramp the remainder of the way into Princetown laden respectively with coffin and ballot-boxes.

"The water in the Devonport leat has been frozen over and otherwise blocked with snow in the neighbourhood of Peatcott, about 3 miles from Princetown. Mr. Francis, the manager, soon had a gang of men at work to clear the obstruction. The leat supplying H.M. Prison, Dartmoor, with water, is in places frozen over; and though large parties of convicts have been hard at work for several days, the supply is still cut off."

On March 29 a snowstorm of great severity occurred over the northern part of England and Wales. At Llanerchymedd, in Anglesey, the melted snow measured 2·35 ins., while over practically the whole of the north of Wales and the north-west of England the amount was over 1 in.

The following cutting from the *Manchester Courier* of March 30 gives a fair account of this snowstorm and accompanying weather:—

"From various parts of the United Kingdom extraordinary cold weather and heavy falls of snow are reported. In the Peak district of Derbyshire the fall has been so heavy that all outdoor work is suspended, and the managements of the railways are preparing against being snowed up. At Barrow and Burnley snow caused stoppage of tramcar services, some streets in the latter town being impassable. A number of people had to go home by cab. In the West Riding of Yorkshire a blinding fall was experienced, the snow around Leeds being in places several feet deep. A blizzard raged at the mouth of the Tyne and over North Westmoreland. In South Shields vehicular traffic became almost impossible. A Norwegian steamer was driven ashore by the heavy South-east gale. In Westmoreland 21 degrees of frost were registered, and travellers over the hills report fearful weather. 26 degrees of frost were recorded at Pitlochry yesterday, this being the most intense that has been experienced this

winter. In the Annandale district of Dumfriesshire snow lies 5 ins. deep. Here, as in other sheep-farming districts, great loss of lambs is feared. At Langholm 25 degrees of frost were registered yesterday. The telegraph and telephone wires are down in great numbers over the affected districts. Intense cold is reported from County Down, where snow has also fallen heavily. In London, after a cold day, rain has fallen. Snow fell heavily in Manchester and district yesterday afternoon and evening. The fall commenced about noon, and rendered pedestrian traffic very unpleasant."

The amount of sunshine during the month was very deficient over the south-eastern portion of the country, the total at many of the stations being only a little over 60 hours, which was only half the amount recorded at stations in the north-west and west.

Although the death-rate was below the average, the deaths due to diseases of the respiratory organs were considerably affected by the severe weather, as will be seen from the following figures in Table II. extracted from the Registrar General's *Weekly Return of Births and Deaths*; the deaths on March 23rd being 152 below the average, while on April 20th they were only 4 below.

TABLE II.—DEATHS IN LONDON.

1901. Weeks Ending	Diseases of the Respiratory System.		Bronchitis.		Pneumonia.	
	Deaths.	Diff. from Average	Deaths.	Diff. from Average	Deaths.	Diff. from Average
March 2	501	- 58	273	- 56	186	+ 11
" 9	463	- 97	233	- 94	197	+ 15
" 16	394	- 124	214	- 89	148	- 19
" 23	332	- 152	172	- 91	126	- 50
" 30	363	- 78	177	- 66	156	- 2
April 6	360	- 51	187	- 32	143	- 8
" 13	345	- 45	162	- 26	152	- 11
" 20	374	- 4	184	- 1	153	- 2

In consequence of the keen and cold weather, vegetation was at a standstill. The agricultural correspondent of *The Times*, on April 1, wrote:—

"Under such conditions as have been described it was hardly possible, except on the lightest and driest lands, to make any substantial progress with field work, and it is not easy to recall a year when at the beginning of April seeding operations have been so backward as is the case to-day. The ground is so cold that even where it was possible to seed the land some weeks ago there are no signs of germination; but this perhaps is fortunate, as no young braird would successfully have come through the ordeal of wind and frost which it would have had to face. It is only necessary to glance at the crocuses in a garden border to see the wreckage that the icy blasts have left in their trail. An immense amount of work will need to be crowded into the next few weeks, and the sowing of barley and oats is likely to encroach upon the time that would better be given to the seeding of mangold and rape. For barley-growers the weather has been exceptionally unfortunate, for in many cases they have missed that opportunity of timely sowing which is regarded as an essential forerunner to a good crop at harvest-time. Vegetation has remained almost

stationary, and March has passed away without leaving behind it a blackthorn blossom to brighten the hedgerows. The appearance of the grass lands changed for the worse last week, and, excepting in favoured situations, they are now browner and barer than at any previous period of the winter season—we dare not speak of spring yet. Sheep have suffered severely from the inclement weather, and the earlier losses in the lambing pens are aggravated by those which are now taking place."

I have to express my thanks to Dr. H. R. Mill for the loan of newspaper cuttings referring to the weather during March, and also to the members of the staff in the Society's office for help in working up the various returns.

DISCUSSION.

The President (Mr. W. H. Dines) said he wished to thank Mr. Marriott on behalf of the Society for his valuable and interesting paper.

Mr. A. J. Hands said he would like to supplement Mr. Marriott's remarks on damage caused by lightning. On March 1, in Cornwall, a chimney shaft was struck, and also a horse and cow were killed in the eastern counties. On the 6th, at Chigwell, two trees by the roadside were damaged, one receiving the discharge and passing it on to the other through the interlacing branches. The water-main in the roadway was also affected; and curiously enough, 100 yards down the road more damage was done, although no connection between the two places could be traced. Mr. Hands also explained how the German church at Dalston was damaged and set on fire by lightning on the 6th. The newspapers reported that the lightning, attracted by the metal pipes of the organ, entered the church through a window in the nave; but he himself had subsequently seen the church, and had traced the damage to a badly connected lightning-conductor.

Mr. H. Southall remarked that the blackthorn was especially late this year. It was on the point of appearing during the first week of March, but did not actually come out till April 14. The earliest date he had ever obtained was March 20, and the latest April 20. It was curious to notice that the coldest period of this last month was just at the time when the average annual curve showed that a great rise in temperature usually set in. In 1830 temperature rose to nearly 70° on March 25, and the heat was so great that farmers were obliged to take the cattle in. A week later, on April 1, a foot of snow was on the ground. March was certainly a month of "many weathers." In 1845 the cold was so severe in March that icicles 6 to 12 inches long were formed by the breath of animals.

Mr. H. N. Dickson said that he had listened to the paper with special interest on account of its bearing on work with which he had been connected for some years, in investigating the influence exerted by the surface waters of the oceans upon climate. A surface temperature below the average in winter gave rise to barometric pressure above the average, and high surface temperature corresponded to low pressure. This relation had been specially noticeable in the winters of 1894 and 1895. He surmised that the continued high temperature of the air during last autumn caused the melting of unusually large quantities of ice in high latitudes, and the consequent delivery of an exceptional amount of ice-cold water in the North Atlantic, and that to this was due the high barometric pressure to the west of the British Isles which controlled the weather of the period discussed in the paper.

Mr. C. Harding said that it was noticeable that the mean maximum

temperature for Greenwich was 4°·7 below the average, but the mean miminum was only 0°·9 below. The means were very similar to those for the previous March, the figures being :—

	Mean max.	Mean min.	Mean temp.
March 1900 . .	44·9	33·8	39·4
„ 1901 . .	45·1	34·1	39·6

The mean temperature for March in 1833 and 1845 was as low as 36°·7. Last month would long be remembered for the number of low-pressure areas in the south of Europe. It was the most remarkable feature of the winter. Probably they were the means of bringing a cooler and drier area over our islands. During the coldest period, from March 26-29, we were on the western side of an anticyclone with an arm bearing direct from Iceland. A strong downward tendency also helped to make the conditions cold as well as dry. The wreckage in the Atlantic was greatly increased last month. Mr. Dines some time ago called attention to the fact that the lowest temperature was often experienced with a falling barometer. This was confirmed here. For the four days March 25-28 the mean temperature at Greenwich was below 40°; and from 10° to 12° below the average. No such instances so late in the month had occurred during the past 60 years.

Mr. F. J. Brodie said that he was much struck with Mr. Dickson's remarks, which could not fail to be of interest to any one who was sanguine enough to believe in the future possibility of seasonal weather forecasts. There was, however, one point to be considered. The peculiarities to which Mr. Marriott had drawn attention were shared by at least two or three recent winters, the salient feature in each case being that the season opened with mild weather but grew colder and colder towards the close. In London the month of February had in five years out of the past seven proved colder than January, and in two years, viz. 1898 and 1899, March was the coldest month of the three, the ordinary march of temperature being thus completely reversed. If one were to attach any substantial value to Mr. Dickson's theory, one would naturally expect that in the case of seasons with general characteristics of so similar a return the preceding sea-temperature conditions would also have exhibited a corresponding similarity, or at all events something approaching it. He (Mr. Brodie) would be glad to know whether this was really the case.

Mr. H. N. Dickson explained that it was not yet possible to speak definitely as to the conditions prevailing during the present winter. The information necessary was obtained from sea observations, which were only available after considerable delay. He merely wished to suggest a possible explanation, derived by analogy from the experience of the earlier years.

The President (Mr. W. H. Dines) said that since the matter had been mentioned by Mr. C. Harding, he might say that he had pointed out that a high barometer and cold weather in winter did not necessarily accompany each other in north-western Europe. He considered that in England at any rate temperature was entirely dependent upon wind direction ; and by wind direction he did not mean a merely local current a few hundred miles broad, but the general drift of the atmosphere. When this was more from the North than usual, as the isobars and the path of the depressions showed it to be at the end of March, unusual cold prevailed. Mr. Marriott's paper had also borne out another assertion he had often made in that room, namely, that the death-rate in the winter depended but very slightly on temperature. This referred of course to the death-rate as a whole and not to the rate from special diseases. The past winter had been most exceptional. It would probably be found that the death-rate from November to March was the lowest ever recorded since the

commencement of the returns; and this low rate had prevailed equally during the warmth of December and January, and the cold of February and the end of March.

Mr. W. MARRIOTT, in reply, said that he hoped the information contained in the paper would be found serviceable. He had on a former occasion read a paper on the Weather of March 1883, which was different from that of March of the present year, as the weather was cold over nearly the whole month, and very dry. The relative humidity in that month was very low over the south coast. Towards the end of March the sun gets much more powerful, and as a rule a rise in temperature of several degrees should be expected then. It was interesting to hear Mr. Southall's anecdotes of the weather of earlier years. He (Mr. Marriott) had received a letter from Mr. D. H. Owen, of Sparkhill, Birmingham, stating that he had been able to take a "turn on the ice" as late as March 29. He also sent a snapshot photograph showing the ice on a flooded field fully exposed to the sun; the ice being an inch and a half thick.

Cloud Observations at Toronto.—Observations for cloud heights, velocities, and directions were commenced at Toronto on September 21, 1896. The length of the base line between the two stations was 5093 ft. Not much photography, however, has been done, owing to the great difficulty encountered in keeping the cameras in adjustment. The observations for 1896 and 1897 have recently been published.

Roughly speaking, the higher *cirrus* during September and October was found to move from the direction of about N. 40° W., while through November, December, January, and February it moved from N. 65° W. at elevations ranging between 26,700 and 33,790 ft., and travelled at velocities varying from 60 to 113 miles per hour. The highest *cirrus* measured during the latter part of the year 1896 was on September 24 at an altitude of 33,790 ft. with a velocity of 79 miles per hour, moving from N. 39° W.; while the lowest was at 26,580 ft., moving at 55 miles per hour from N. 64° W., on October 29.

Medium-height clouds, such as *alto-cumulus*, *cirro-stratus*, etc., seem to occupy a height of from 13,120 to 22,970 ft., travelling in the directions varying between S. 50° W. and N. 50° W. at velocities of from 30 to 70 miles per hour.

Lower *cumulus* clouds generally come from the south-west and north-west at altitudes of 3940 to 8200 ft., with velocities of from 10 to 45 miles per hour.

Of the lower cloud drift, such as *scud*, some observations have been obtained at elevations of 2130 to 3280 ft., with velocities of about 25 miles per hour.

During January 1897, the weather was very cloudy and unfavourable for observation, the sky being generally clouded with low *stratus*, or if partially clouded the edges of the clouds were ill defined.

In February a good deal of low *cumulus* prevailed, generally at an elevation of about 3280 ft., and moving from between S. 77° W. and N. 88° W. The highest *cirrus* measured during this month was 29,860 ft., moving at the great velocity of 138 miles per hour from S. 78° W. This was on February 17, and the next day *alto-cumulus* clouds prevailed at 22,970 ft., coming from S. 83° W. at 100 miles per hour.

March was unfavourable for measurements, and no high clouds were measured.

During April *cirrus* clouds floated at altitudes of from 31,170 to 36,420 ft., their average direction being from the north-west. On the 28th occurred the highest cloud, being 36,420 ft. high, coming from N. 28° E. at 86 miles

per hour. The average velocity of the *cumulus* clouds this month was 20 miles per hour at 5250 ft.

May did not offer any very high clouds for measurement. Some *cirro-cumuli* reached an altitude of 32,810 ft. at a velocity of 92 miles per hour from the N. 17° W., most of the cloud display being of the *cumulus* and *strato-cumulus* formation, their general direction being from S. 45° W., velocity 30 miles per hour, and altitude 7220 ft. A beautiful display of *mammato-cumulus*, drifting from the west very rapidly, occurred on the 12th about 2 p.m.

In June quite a number of observations were obtained of *cirrus* clouds. The highest cloud measurements made up to this date occurred on June 14, when a fine display of *cirrus* in two strata occurred. The upper *cirrus* was at an elevation of 38,710 ft., travelling from N. 20° W. at the high velocity of 148 miles per hour; the lower stratum, 3280 ft., below the upper *cirrus*, moving at 112 miles per hour from N. 9° W. *Cumulus* and *alto-cumulus* clouds prevailed during the month, moving from between N. 10° W. to N. 50° W. at moderate velocities, generally from 10 to 30 miles per hour. Another fine display of *cirrus* occurred on the 28th, in which an altitude of 37,525 ft. was obtained, with a velocity of 109 miles per hour from N. 52° W.

During July some *cirro-cumulus* averaging 25,967 ft. in altitude was measured, and *cumulus* clouds from the north with a velocity of 15 miles per hour at an elevation of 5250 ft. about the middle of the month.

No cloud measurements were made in August until towards the end of the month, when a number of *cumulus* were observed at elevations of 4270 to 5900 ft. coming from the west-north-west at a velocity of 15 miles per hour; some very rapidly moving *cirro-stratus* at an altitude of 28,220 ft., moving from the west with a velocity of 90 miles per hour, occurred on the last day of the month.

During September *cirrus* and *cirro-cumulus* clouds prevailed, and some very high *cirro-cumulus* having a comparatively slow movement at an elevation of 36,090 ft. were measured. On the 24th occurred some well-marked *alto-cumulus* 12,140 ft. high, travelling at 10 miles per hour from the north-north-east.

During October a number of observations were made on *cirrus*, *cirro-cumulus*, and *alto-cumulus* clouds, some very high altitudes occurring, the highest being about 39,370 ft., but moving slowly from a general direction of west-north-west; average velocity about 30 miles per hour.

The reduction of the observations, though simple, entails a mass of figures which makes the work very laborious and tedious, and it is to be regretted that owing to the nature of the observations a number had to be rejected, which leaves the balance of reliable determinations rather scanty.

VAPOUR-TENSION IN RELATION TO WIND.

BY RICHARD STRACHAN, F.R.Met.Soc.

[Read April 17, 1901.]

A STUDY of the monthly mean tension of vapour at extreme cardinal positions of the British Islands, to which the Isle of Man is central, for the years 1896, 1897, and 1898, has led to some results which may be of interest to the Fellows. The data used are contained in the *Monthly Weather Reports* issued by the Meteorological Office.

The tension of vapour decreases from south to north, and from west to east of these islands, according to nearly all these monthly values; but in November 1896 the decrease was southward, and in October 1898 it was westward. For some months, in the central district, it was higher, for some lower, than it was east and west. It is greatest in July or August, least in February or March. Its gradient is greatest in July, ·0116 inch of mercury per degree of great circle; least in January, ·0058 inch.

Comparing the resultants of the tension of vapour with the corresponding resultants of the winds, the inferences are: In summer they are similar in direction, in the other months the vapour-resultants are to the left of the wind-resultants, the observer standing with his back to the wind. The vapour-resultant is about 3 points to the left in winter; in some months to the right in spring; with the wind in summer; about 5 points to the left in autumn. It was 10 points to the right in January 1897, when the wind-resultant was North-east feeble; 11 points to the left in the following February, wind South-south-west strong; 10 points to the left in the next April, wind South feeble. Seemingly—though the data are too scanty for precision—the maximum angle to the left is with South-west wind-resultants, to the right with North-east. The relation which is the most frequent is in correlation with the monthly rainfall. For the rainfall is greatest where the wind-resultant strikes the land, large 90° to its left, least at 180°, and moderate 90° to the right. Thus, for a wind-resultant from West, the rainfall is largest at west and north, less at south and east positions, while the vapour-resultant may be about west-north-west. The general relation of the vapour-resultant to the wind-resultant thus appears to be in accordance with the law of the vertical succession of wind-currents from the surface of the earth, which has been stated as follows: "Stand with your back to the wind, and the successive layers of cloud will come continually more and more from your left hand. In the Southern Hemisphere the succession is reversed; that is to say, the upper currents come more and more from the right."

The term "resultant of vapour-tension" is perhaps objectionable, but it is calculated in the same manner as the resultant of winds, using tension instead of number of winds. Thus, excess of vapour-tension in the south position above that in the north indicates, I take it, a tendency of the vapour to come from the west; let it be x: an excess in the east above that in the west indicates a tendency of the vapour to come from

south, y. The result of these two tendencies is an advance of vapour from between west and south, from $\tan \phi = \frac{y}{x}$, easily solved by means of a Traverse Table.

Having performed the monthly calculations for my own curiosity, I did not keep the materials or the working—only the results. I had no intention of writing a paper, but after generalising the results I thought the inferences had some value. As a specimen of the working, I use the *Monthly Weather Report* for January 1901 :—

Position.	Vapour-tension. in.	Diff.	Indicates from		
N.	·216	·035	West.	= N.W.	The resultant of the winds was S.S.W.; hence the vapour current was 10 points to the left of the wind's course.
S.	·251				
W.	·242	·035	North.		
E.	·209				
C.	·225				

Weather Forecasts by Wireless Telegraphy.—Tammasina, the Italian physicist, has adapted the receiving apparatus used in wireless telegraphy of the Marconi type to follow the course of distant thunderstorms, and even to forecast rainy weather twelve hours in advance. The apparatus consists essentially of a coherer, with its vertical wire, an electro-magnet, a dry cell, and a telephone. Experiments were carried out at Geneva with this apparatus, which was fully described before the Paris Academy of Sciences. When a storm was passing over, discharges were indicated by an electric bell, the strength or distance of the discharge being indicated by the vigour of the stroke of the bell. When the weather changed without a thunderstorm, a peculiar crackling was always heard in the telephone, and rain could be predicted by this means with great certainty 12 hours in advance. Tammasina considers that his apparatus would be of great use on ships at sea for predicting storms, and he is of opinion that it is much more reliable than the present instruments used for predicting the weather.—*The Electrical Review.*

"**A Feeding Storm.**"—Writing from Edinburgh to Morritt of Rokeby on January 21, 1815, Sir Walter Scott says the weather in Midlothian "seems setting in for *a feeding storm*," and adds the explanation that the name is given "when the snow lies so long that the sheep must be fed with hay." Sir Walter's knowledge of country life was so wide and exact that it would be bold to differ from him without hesitation. It may perhaps be permissible to mention an individual impression even against a statement with authoritative credentials of the highest order. "A feeding storm" is recognised in Scottish districts that are not pastoral in character, and the meaning attached to it in such places is that of a lingering period of snowy weather when the snow actually on the ground is increased or fed by intermittent falls. This, no doubt, is the kind of weather that necessitates hand feeding, as flock-masters call the tedious process of giving their animals artificial supplies, and so far the non-pastoral usage and Sir Walter Scott's definition are at one. At the same time the former overlaps and indeed includes the latter, just as it does another which attributes the term "feeding storm" to the well-known voracious habit of birds in immediate anticipation of a prolonged visitation of snow.—THOMAS BAYNE, in *Notes and Queries*, July 6, 1901.

REPORT OF THE COUNCIL

FOR THE YEAR 1900.

THIS year will long be memorable in the annals of the Society as marking the Jubilee of its existence, and owing to the great loss which it has sustained in the death of its distinguished Fellow, Mr. G. J. Symons, F.R.S. Mr. Symons was struck down by paralysis a few days after he had been, for the second time, elected President, and he died on March 10, less than one month prior to the Society's Jubilee.

On February 21 Mr. Symons resigned the Presidency, the duties of which he had, owing to illness, become unable to fulfil, and on the same day the Council, under By-law 5, appointed their Treasurer and former President, Dr. C. Theodore Williams, to fill the vacant chair. The vacancy in the Treasurership, caused by the acceptance of the Presidency by Dr. Williams, was filled on March 21 by the appointment of Mr. R. Inwards. Both these gentlemen hold office until the Annual General Meeting.

The Jubilee preparations, and the large additions to the Library, have necessarily thrown much extra labour on the staff, and have prevented them from working off the arrears in the issue of the *Meteorological Record*, which is again somewhat behindhand. The Council desire to express their appreciation of the zeal with which the staff have carried out their work.

The Council mention with special regret the deaths of Dr. W. Marcet, F.R.S., past President, and of Mr. E. J. Lowe, F.R.S., one of the founders of the Society. There is now only one surviving founder, viz. Mr. J. Glaisher, F.R.S.

Committees.—The Council have been materially assisted during the year by the following Committees :—

EDITING COMMITTEE.—Messrs. F. C. Bayard, R. Bentley, R. Inwards, and R. H. Scott.

GENERAL PURPOSES COMMITTEE.—The President, three Secretaries, Treasurer, Messrs. W. Ellis and B. Latham.

JUBILEE CELEBRATION COMMITTEE.—The President, Vice-Presidents, Treasurer, three Secretaries, Mr. R. H. Curtis, and Dr. H. R. Mill.

WIND FORCE COMMITTEE.—The President, three Secretaries, Messrs. R. H. Curtis, W. H. Dines, and C. Harding, Capt. M. W. C. Hepworth, Mr. R. Munro, Sir C. E. Peek, and Capt. D. Wilson-Barker.

The Jubilee.—A detailed account of all the proceedings in connection with the Jubilee has already appeared in the *Quarterly Journal* (Vol. XXVI., p. 173), but the Council feel that thanks are due to the several Societies which so heartily co-operated with the Council in making the event a complete success. In connection with the occasion a bronze medal, with a portrait of Luke Howard on the obverse, was struck, and a copy presented to each delegate and to all the Honorary Members.

Meetings.—With the exception of those in May and June, which were held in the afternoon in the Society's rooms, 70 Victoria Street, the Meetings of the Society were held as usual, by the courtesy of the President and Council of the Institution of Civil Engineers, at their Rooms, Great George Street, Westminster.

The late G. J. Symons, F.R.S.—An account of the proceedings consequent upon the lamented death of Mr. Symons and of his bequests to the Society have appeared in the *Quarterly Journal* (Vol. XXVI., p. 155). His Cross as Chevalier of the Legion of Honour, the Albert Medal, the Society of Arts Silver Medal, and the Presentation Album are now in the Society's possession, and in addition it received a legacy of £200 and a very large number of books (about 2200 volumes and 4000 pamphlets). Mr. Symons also had prepared a Meteorological Bibliography, containing between 60,000 and 70,000 titles. As the Council thought that such a valuable work should be in the possession of the Society, they offered the sum of £100 for the same, and are pleased to report that the executor has accepted this offer, and that the Bibliography is now in the Society's Library.

Symons Memorial.—Steps have been taken to organise a permanent memorial to our late President, the Executive Committee numbering friends of Mr. Symons in addition to Fellows of the Society. It may be stated that the memorial will probably take the form of a Gold Medal.

Quarterly Journal.—This publication has contained, besides the account of the Jubilee proceedings, several papers of great interest, amongst which may be mentioned the Presidential Address on "A New Reduction of the Meteorological Observations at Greenwich," by Mr. F. C. Bayard; "The Diurnal Variation of the Barometer in the British Isles," by Mr. R. H. Curtis; "The Climatic Conditions necessary for the Propagation and Spread of Plague," by Mr. Baldwin Latham; and "The Wiltshire Whirlwind of October 1, 1899," by the late Mr. G. J. Symons, F.R.S.

Meteorological Record.—Three quarterly parts have been issued during the year, bringing this publication down to the end of 1899.

Wind Force Experiments.—These experiments are still being continued on H.M.S. *Worcester* and at Stone Ness Point.

Medal to Cadets on H.M.S. Worcester.—The Society's silver medal was this year awarded, on the recommendation of the examiner appointed by the Council, to Cadet R. A. Melhuish for the best essay sent in, on "The Meteorology of the Indian Ocean."

Stations.—Observations have been accepted from the following new station, viz. Bournemouth, Hants.

Inspection of Stations.—All the stations south of 52° N. lat. and east of 2° W. long., as well as such new stations as could be conveniently visited, were inspected, and found to be on the whole in a satisfactory condition. Mr. Marriott's report will be found in Appendix II. (p. 206).

Phenological Report.—This Report was, as usual, prepared by Mr. Mawley, to whom the Society owes its best thanks, and was read at the February meeting. Additional observers are much wanted in the following districts:—Ireland, south; England, north-west; and Scotland, east and west.

Library.—The Council have requested Mr. Marriott to write some account of the books and pamphlets in the Symons bequest, and this will appear later on in the *Quarterly Journal.* This will give a much better idea of the value of this noble bequest than any list of titles. A list of the other additions to the Library will be found in Appendix V. (p. 225).

Finance.—The Fellows will be pleased to know that the whole of the expenses connected with the Jubilee have been paid by the Members of

the Council, so that the Funds of the Society have not been called upon; and that Mr. Bentley kindly placed at the disposal of the Society for three months the services of a gentleman to assist in the work connected with the Jubilee celebration.

Fellows.—The changes in the number of Fellows are given in the following Table, which shows an increase of fifty-five during the year:—

Fellows.	Annual.	Life.	Honorary.	Total.
1899, December 31	400	147	18	565
Since elected . . .	+ 80	+ 7	+ 2	+ 89
Since compounded .	− 1	+ 1	...	0
Deceased	− 8	− 11	...	− 19
Retired	− 13	...	...	− 13
Struck off	− 2	...	...	− 2
1900, December 31	456	144	20	620

Deaths.—The Council have to announce with much regret the deaths of the following Fellows:—

George Robert Andrews, F.R.G.S. (died in 1899)	elected	May 20, 1896.
Lord Armstrong, C.B., F.R.S., M.Inst.C.E.	„	Mar. 24, 1857.
Charles Harrison Blackley, M.D., M.R.C.S.	„	Jan. 18, 1888.
Charles Coppock, F.R.A.S., F.R.M.S.	„	April 20, 1864.
Lord Farnham, F.R.A.S.	„	Nov. 19, 1890.
Rogers Field, B.A., M.Inst.C.E.	„	Feb. 15, 1865.
Thomas Gustav Hawley, F.G.S.	„	Mar. 21, 1883.
William Johnson, F.R.A.S. (died in 1886)	„	April 4, 1850.
Henry Manley Lambert, R.N.R.	„	June 15, 1892.
Henry Law, M.Inst.C.E.	„	June 20, 1877.
Sir John Bennett Lawes, Bart, LL.D., F.R.S.	„	June 15, 1864.
Edward Joseph Lowe, F.R.S., F.R.A.S., F.L.S.	„	April 3, 1850.
William Marcet, M.D., F.R.S., F.C.S.	„	Nov. 15, 1876.
John M'Landsborough, F.G.S., F.R.A.S.	„	Mar. 16, 1860.
John Parnell, M.A., F.R.A.S.	„	June 15, 1881.
Edward Pritchard, M.Inst.C.E., F.G.S.	„	Jan. 16, 1895.
William Tucker Radford, M.D., F.R.A.S.	„	June 15, 1864.
Thomas Glazebrook Rylands, F.L.S., F.G.S.	„	June 15, 1881.
George James Symons, F.R.S.	„	Mar. 25, 1856.

APPE

STATEMENT OF RECEIPTS AND EXPENDI

RECEIPTS.

Balance from 1899		£19
Subscriptions for 1900	£743 0 3	
Do. for former years	42 17 0	
Do. paid in advance	30 0 0	
Life Compositions	168 0 0	
Entrance Fees	82 0 0	
		106
Meteorological Office—Copies of Returns	£104 16 6	
Do. Grant towards Inspection Expenses	25 0 0	
		12
Dividend on Stock (including £48 : 8 : 3 from the New Premises Fund)		14
Sale of Publications, &c.		8
Legacy of £200 by the late Mr. G. J. Symons, F.R.S.—less Duty		180
Mr. B. Latham—Cost of printing paper on Plague		40
Mr. C. Hawksley—Donation for Library		5
Surplus on Jubilee account		6
		£176

APPENDI

ASSETS AND LIABILITIE

LIABILITIES.

To Subscriptions paid in advance	£30 0 0	
,, Rent for quarter ending December 25, 1900	50 0 0	
		£80 0
,, Excess[1] of Assets over Liabilities		3655 15
		£3735 15 3

[1] This excess is exclusive of the value of the Library, the Stock of Publications, and the Symons Bibliography and Bequest of Books.

WM. MARRIOTT, *Assistant-Secretary.*

NEW PREMISES FUND,

Amount paid to the Society's Funds towards the rent of rooms at 70 Victoria Street	£48 8 3

RESEARCH FUND,

Amount invested in the purchase of £3 : 2 : 3, 2¾ per cent Consols . . .	£3 1 6

'HE YEAR ENDING DECEMBER 31, 1900.

EXPENDITURE.

'nal, &c.—		
Nos. 113 to 116	£152 3 0	
ions	107 14 1	
Copies	17 18 0	
ogical Record, Nos. 74 to 76	51 5 0	
from Registrar-General's Reports	3 18 7	
		£332 18 8
ıting, &c.—		
Printing	£22 7 0	
'ellows, By-Laws, and Observation Books	33 15 0	
ry	20 7 8	
Receipt Forms	8 8 0	
ıd Bookbinding	8 18 6	
		93 16 2
e Expenses—		
	£509 2 7	
l Housekeeper	200 0 0	
ighting, and Insurance	15 10 9	
&c.	7 8 11	
	74 10 10	
ṛpenses	17 9 10	
ıents at Meetings	12 9 9	
ıp new Bookcases	162 5 0	
t's Fees	10 16 9	
Duty on the Books of the Symons Bequest	18 0 0	
l of Books from Camden Square	5 4 3	
ə of the Symons Bibliography	100 0 0	
		1132 18 8
:rvations—		
ɔn	£51 19 9	
's	9 2 0	
ənts	1 19 7	
		63 1 4
k—		
ə of £50 L. & N. W. R. Stock at 198½		99 17 6
		£1722 12 4
ance—		
:	£33 19 7	
ı of the Assistant-Secretary	12 2 10	
		46 2 5
		£1768 14 9

Examined and found correct,

FRED^C. GASTER, *Auditor.*

uary 8, 1901.

APPENDIX II.

INSPECTION OF STATIONS, 1900.

All the stations south of 52° N. lat. and east of 2° W. long., as well as several others, have been visited, and were found to be mostly in a satisfactory condition.

The number of thermometers which have been tested has been 202, in 18 of which there was an alteration of zero. Ten rain-measuring glasses have also been tested, all of which were satisfactory.

The photographs which I have taken of the stations, and which are mounted in the album, show that at many of them there is a continual growth of trees year by year. It becomes necessary to watch this growth, and to have the trees cut back or thinned out, otherwise the exposure of the instruments may become too confined.

At a few of the stations changes had been made in the position of the instruments without information being first sent to the Society of the proposed change. This I much regret, as at two of them the changes were unsatisfactory At Scarborough, owing to building operations, the instruments had to be removed in July from the site where they had been placed since the beginning of the year. The Corporation, however, did not provide a fresh site, so the observer (the Borough Meteorologist) had to put the instruments in his allotment garden, over bare soil. At Weston-super-Mare the instruments had also to be removed owing to the building of the new Post-Office, and they were then placed on the leads of the roof of the Town Hall. I have made strong representations on these points to the authorities, and believe that steps are being taken to expose the instruments in accordance with the regulations of the Society.

As the observations from the two sets of instruments at St. Luke's, Old Street, have been carried on for more than twelve months, I have recommended that the old set be removed at the end of the current year. The results show that there is practically no difference in the temperatures, but that the new gauge collects a little more rain with certain winds than the old gauge, which is much protected by trees.

Since my last report a new Campbell-Stokes sunshine recorder has been set up at Regent's Park alongside of the old recorder, and the comparison shows that the latter has become very defective and records much too little sunshine, as will be seen from the following figures:—

	New Recorder.	Old Recorder.	Deficiency.
February . .	47·1 hours.	36·1 hours.	23 per cent.
March . .	64·7 ,,	42·4 ,,	34 ,,

WM. MARRIOTT.

October 16, 1900.

NOTES ON THE STATIONS.

ADDINGTON, *September* 14.—This station was in good order. On testing the thermometers it was found that the dry and wet had both gone up 0°·1, and that the minimum had gone down 0°·3.

ASPLEY GUISE, *September* 13.—The thermometer screen required painting. The trees and shrubs have grown considerably since the instruments were first placed in position. The two rain-gauges are surrounded by wire netting, with the object of birds perching on it instead of on the rim of the gauge. The wire netting round the monthly gauge was too high.

BATH, *July* 12.—The instruments are placed in a railed-off enclosure in the Henrietta Park, and are well exposed. The sunshine recorder is placed on the dome of the Guildhall. The only obstruction is the pinnacle of the tower of the Abbey Church, which makes an angle of 18°. The instrument required adjustment, as the trace was not parallel with the card. A self-recording Dines pressure-tube anemometer is also mounted on the dome of the Guildhall. The head of the anemometer is carried up to the top of a mast 37 feet high. A Richard barograph is also in use. Dr. Symons has a number of climatological stations round Bath for comparative purposes.

BEDDINGTON, *September* 14.—On comparing the thermometers it was found that the minimum had gone down 0°·3. As one of the brass clips holding the tube of the dry bulb was broken off, I put on a new one. The exposure is more confined than when the station was first started, as the trees have grown considerably.

BENNINGTON, *September* 18.—Everything at this station was clean and in good order.

BERKHAMSTED, *September* 12.—The sunshine recorder was not in proper adjustment for time, the spot of light being about 15 minutes fast. I readjusted and securely fixed the recorder. Three grass minimum thermometers are in use, two of which had spirit at the top of the tube. At the previous inspection I found the Hicks "climax" grass minimum had gone down 5°·1. On again testing the thermometer, I found that it had gone down still more, and that it was reading 7°·3 too low. All the other instruments were in good order.

BEXHILL, *July* 25.—The grass minimum had some spirit at the top of the tube. I recommended that there should be more space between the cover of the water receptacle and the wet-bulb.

BOGNOR, *July* 18.—I recommended that fresh screws be used for suspending the maximum and minimum, and that they be tightened; also that the maximum should be inclined, in order to counteract a break in the column of mercury. There was a little water in the rain-gauge, although there had been no rain that day. I impressed upon the observer the necessity of always looking in the gauge each day.

BOURNEMOUTH, *January* 24.—This station is at Kempsey, in Bath Road, on the East Cliff. The instruments are in the kitchen garden on the north side of the house, and have a good exposure. Mr. Colvile has a Campbell-Stokes and also a Jordan sunshine recorder on the roof of the house. A stack of chimneys cuts off the sun from the Campbell-Stokes recorder in the winter for a certain time, but the amount lost is recorded by the Jordan. The recorders are not worked in the summer, as other chimneys cut off the sun. I recommended that the recorders be raised so as to be clear of the chimneys. I visited this station again on August 31, and found the instruments clean and in good order.

BRIGHTON, *July* 17.—The thermometers and rain-gauge had been moved to the eastern side of the Steyne Gardens, owing to the erection of a bandstand. The exposure is good, except for the rain-gauge, which is under the influence of some trees. I recommended that the gauge should be moved more to the westward. A Negretti and Zambra self-recording rain-gauge had been in use for

some months. It was, however, choked up with dust. It did not record as much rain as actually passed through the instrument. This was subsequently set right by adjusting the screws under the buckets. The grass minimum had some spirit up the tube. The sunshine recorder is on the roof of the Town Hall. The ball was not in the centre of the frame, and required adjustment. The maximum was mounted with the bulb slightly higher than the other end. There appeared to be a tendency for the mercury to run up the tube when shaken. I recommended that the bulb should be lowered, and that care should be taken always to see that the mercury was continuous from the contraction.

CHELMSFORD, *September* 21.—The instruments were in good order, but the thermometer screen required painting.

CRANLEIGH, *July* 16.—This station was not in a satisfactory condition. The maximum was mounted near the top of the screen, and so cut off the view of the mercury in the dry and wet; this led two of the observers to read the dry incorrectly. A tin canister was used for the water receptacle, which was not only rusty, and so fouled the water, but also surrounded the wet-bulb and prevented the free circulation of the air. I recommended that a glass vessel be used, and that proper attention be paid to the wet-bulb, and also that the maximum and minimum be altered in position. The pipe of the rain-gauge funnel was broken off. The thermometer screen required strengthening and painting. The grass in the enclosure had not been cut, but had been allowed to go to seed. The observations were taken by two of the boys in the school. This arrangement did not work satisfactorily, so I recommended that the Clerk should be appointed the observer.

CULLOMPTON, *August* 18.—There was no change in the zeros of the thermometers. The sunshine recorder was in good adjustment. I called attention to a tree on the east-north-east, and also to one on the west-north-west, which required their tops to be cut off. A bed of marigolds had been planted on one side of the rain-gauge, and these had grown up too close. I requested that those near the gauge should be cut down.

EASTBOURNE, *July* 25.—There was no change in the zeros of the thermometers. The instruments were in good order.

FOLKESTONE, *July* 24.—The muslin and cotton on the wet-bulb were too thick. The rain-gauge had been moved to a more open situation on the south side of the hospital buildings. A new large block had been erected about two years previously, and the sunshine recorder had been placed on the top of the building, where the exposure is very good.

GRAYSHOTT, *July* 20.—The tube of the maximum had slipped down 2°. This I readjusted and made secure. The sunshine recorder is mounted on a specially erected staging in front of the stables. The exposure is good, except for two or three fir-trees which required their tops to be cut off. It will be necessary to watch other trees, as they are growing rapidly.

GUERNSEY, *August* 24.—On comparing the thermometers it was found that the minimum had gone up 0°·2. The screen required to be painted and also to have fresh posts. I recommended that the hook in the Glaisher rain-gauge should be made into a straight tube, and also that a bottle or can be placed inside the gauge. The Jordan sunshine recorder was set for lat. 39° instead of 49°.

HALSTEAD, *September* 21.—On comparing the thermometers, it was found that the dry-bulb had gone up 0°·1, and the minimum 0°·2. There was a thick incrustation of lime on the bulb of the wet thermometer.

HARESTOCK, *August* 28.—This station was in good order. Colonel Knight

has started some additional earth thermometers, including one of the Symons pattern at the depth of 2 feet.

ILTON, *August* 21.—This station is six miles north of Chard, and eight miles south-east of Taunton. The instruments are in the Vicarage grounds. The Rev. E. B. Poole is using the instruments formerly belonging to his brother, the late Rev. H. J. Poole at Stowell. On comparing the thermometers it was found that the dry had gone up 0°·1, and that the earth thermometer had gone up 0°·5.

ISFIELD, *July* 26.—The tube of the maximum had slipped down nearly 2°. This I readjusted, and also altered the position of the screws, as the mercury in the tube showed a tendency to jump up about 2°. The sunshine recorder required readjustment, as it was set for lat. 43°, and the trace was 15 minutes slow. Major King was away with his regiment, but the observations were being taken very well by a lad. The 9 p.m. observations had, however, been discontinued.

MARGATE, *July* 23.—There was no change in the zeros of the thermometers. The minimum had 1° of spirit up the tube. The thermometer screen required strengthening. The sunshine recorder was not in proper adjustment. The east side was 7° higher than the west; and the time was half an hour slow. The pedestal also was loose.

MARLBOROUGH, *July* 11.—The muslin on the wet-bulb was completely dry, and the thermometer was reading the same as the dry-bulb. I recommended that more attention should be given to the working of the wet-bulb. The thermometer screen required painting. The grass minimum had some spirit up the tube. The sunshine recorder was not satisfactorily mounted, and was out of adjustment, being half an hour slow. I arranged for a carpenter to put up a fresh support, on which I fixed and adjusted the recorder. One of the senior boys has charge of the sunshine recorder and the anemometer. The Science master takes the other observations. The readings are copied into a register, which is re-copied by another person.

OLD STREET, LONDON, E.C., *September* 17.—There was no change in the thermometers. There is but little difference between the readings of the thermometers in the old and new screens. The range between the maximum and minimum in the new screen is about 1° more than in the old screen. The trees round the old rain-gauge have grown still more, and almost overhang the gauge. I recommended that the observations from the thermometers in the old screen and from the old rain-gauge should be discontinued at the end of the year. As the mercury in the new maximum thermometer occasionally ran up the tube, I recommended that the instrument be suspended with the bulb slightly lower than the other end.

PORTSMOUTH, *July* 18.—The instruments were still at the Milton Hospital, but it was proposed to move them shortly to a site in the Victoria Park near the Town Hall, where there would be a better exposure.

RAVENSCAR, *September* 7.—Ravenscar is between Whitby and Scarborough on Robin Hood Bay. The ground is high, being 600 ft. above sea-level. The instruments are placed in a railed-off enclosure close to the railway station, and have a very good exposure. I gave the observer instruction in the manipulation of the instruments and in the method of taking the observations. On testing the thermometers it was found that the minimum had gone down 0°·2.

REGENT'S PARK, LONDON, N.W., *September* 17.—The thermometer screen required cleaning and painting. The grass minimum had 4° of spirit up the tube. The rim of one of the rain-gauges was broken, and required re-soldering.

A new sunshine recorder had been recently set up alongside the old one, which seemed to have deteriorated still more, and to be recording less sunshine. The new recorder was not in proper adjustment for time, being about 15 minutes fast. I recommended that the tops of two trees on the north-east and south-west should be cut off, as they appeared likely to intercept the winter sunshine.

ROUSDON, *August* 20.—There was no change in the zeros of the thermometers. I recommended that buttons be put below the maximum and minimum thermometers to prevent them shaking in strong winds. The ball of the sunshine recorder was not quite in the centre of the frame. The ball weighed 3 lbs. Sir Cuthbert Peek had two other balls, one of which weighed 2 lbs. 15½ oz., and the other 3 lbs. 1 oz. One ball is slightly larger than the other, and also denser in colour. The new ball was put up on July 1, 1899, and since then there has been more sunshine recorded.

SCARBOROUGH, *September* 7.—The Corporation towards the end of last year (1899) appointed Mr. W. W. Larkin as Borough Meteorologist, and he commenced his duties on January 4. A new set of instruments had been obtained, and these were placed in a garden at the eastern side of St. Nicholas House, until July, when they had to be removed, owing to building operations. They were then placed in the Peasholm Allotments at the north end of the town. As the thermometer screen was over bare soil and close to steep sloping ground on the west, I recommended that a portion of ground farther to the south-east be railed off, and grass laid down, and the instruments placed therein. The sunshine recorder would also, when put on a post, have a very fair exposure, as the only obstruction, viz. houses on the east and south-east, make an angle of 5° or 6°. The barometer is mounted on gimbals in a room at St. Nicholas House. On testing the thermometers it was found that the minimum had gone down 0°·5.

SHAFTESBURY, *August* 30.—There was no change in the zeros of the thermometers. The wet-bulb was not working properly. I recommended that a fresh water receptacle be used. I also altered the position of the maximum and minimum in the screen. I recommended that the 2-feet earth thermometer be placed close to the 1-foot. The rubber round the bulb of the 1-foot occasionally became jammed in the tube, so I removed it, and also covered the cap with gutta-percha to prevent rain from getting into the tube.

SLOUGH, *July* 10.—The dry and wet bulbs have magnifying lens fronts. On comparing them it was found that the dry had gone up 0°·6 and the wet 0°·3. I recommended that the thermometers be rearranged in the screen, and also that back plates with hole and slot be put on the maximum and minimum. The thermometer screen is in a somewhat sheltered position. The rain-gauge is on a lawn in another part of the grounds. It is well exposed, although there are some tall trees not far off. The sunshine recorder is mounted on a stone by the side of the steps on the front lawn. The exposure is interrupted by trees on the south-east and west; those on the south-east being 10° and those on the west 15°. The ball required readjusting.

SWARRATON, *August* 28.—On comparing the thermometers it was found that the maximum had gone up 0°·1. The covering of the wet-bulb needed changing. I recommended that muslin be employed instead of the kind of covering used, which was too thick.

TENTERDEN, *July* 24.—The sunshine recorder was not in proper adjustment for time, the wooden support on which it was mounted being movable. I recommended that this be made a fixture. The recorder is exposed in the front garden in the morning, and in the back garden during the latter part of the day.

THURLOW, *September* 26.—On comparing the thermometers it was found that the wet had gone up 0°·1 and that the maximum had gone up 0°·2. As the trees round the thermometer screen have made the exposure rather confined, I recommended that the screen be removed to the adjoining field close to the rain-gauge. The maximum had occasionally got out of order, owing to the contraction not being sufficient to keep the column of mercury up the tube. The thermometer was returned to the makers to be set right.

TORQUAY, *August* 17.—Mr. F. March had recently been appointed Borough Meteorologist in place of Mr. A. Chandler, who had resigned. The instruments were in the same position as formerly, but it was proposed to remove them to another site in the Princess Gardens, close to the entrance to the pier, so that they might be made more public. It appeared to me that the site was not a suitable one for a station of the Royal Meteorological Society. I therefore recommended that the climatological station should remain at Cary Green. As it is proposed to discontinue the station at Chapel Hill, I suggested that the instruments from that station might be placed in the Princess Gardens for public use, and a comparison made between them and those at Cary Green. It is proposed to erect a hut on the west side of the pier, and to mount the sunshine recorders and the anemometer on the top. There is a hill to the east which makes an angle of 6°. If the sunshine recorders were raised to a height of 15 ft. there would not be much loss of sunshine.

TUNBRIDGE WELLS, *July* 27.—The Campbell-Stokes sunshine recorder was not in proper adjustment, the ball being too high, and the instrument set for lat. 49° instead of 51°. The Jordan recorder was also not in proper adjustment for latitude. Mr. Smart has 4 solar thermometers in vacuo on the tower, viz. with black, blue, brown, and white bulbs. On comparing the thermometers it was found that the wet-bulb had gone up 0°·1.

VENTNOR, *July* 19.—There was no change in the zeros of the thermometers. The mercury in the maximum had a tendency to jump or run up the tube, so I recommended that the instrument be mounted slightly inclined. I advised the observer to use a better conducting-thread for the wet-bulb. The sunshine recorder was in good adjustment. The cards, however, had a little play in the grooves. The under cliff cuts off the sun north of west. It makes an angle of 5°. A second 5-inch rain-gauge was placed near the sunshine recorder. The observer, however, had discontinued the records, as they agreed so closely with those from the other gauge. I recommended that the contents of the gauge be measured monthly.

WALLINGTON, *September* 14.—On comparing the thermometers, it was found that the dry and wet had gone up 0°·1. The thermometer screen required painting. The sunshine recorder needed adjusting, as it was 20 minutes slow in time.

WESTON-SUPER-MARE, *August* 16.—I found that owing to the building of the new Post-Office close to the meteorological instruments, it had become necessary to remove them to another place, and that the observer had put them on the roof of the Town Hall. As this was a departure from the regulations of the Society—which require the instruments to be placed over grass, with the thermometers 4 ft. above the ground,—I pointed out that the observations would not be comparable with those at other stations, and urged that the instruments, or rather a new set, should be placed in the churchyard on the western side of the Town Hall, where there is a good exposure. A Campbell-Stokes sunshine recorder (universal pattern) had recently been set up. The exposure is good, except on the west-north-west, where there is a church tower; and also a church spire on the east-south-east. The instrument was not in

proper adjustment, being set for lat. 39° instead of 51°. A straight card was also being used in place of a long, curved one.

WEYMOUTH, *August* 22.—On comparing the thermometers, it was found that the wet-bulb had gone up 0°·1. The posts of the thermometer screen were rotten, so I recommended that new posts be put in. A Dines portable pressure-tube anemometer was in use. The sunshine recorder had been remounted, and is now on a stout post on the north-east side of the house at the end of the pier. At the time I saw the card the spot of light was nearly an hour fast. The man who attends to the instrument informed me that the card had been put in correctly, but that the wind (which was blowing strongly at the time) had caused the shifting of the card. I recommended that the card be kept in position by clips on each side.

WINTERSLOW, *August* 29.—The thermometers had not been verified, except the 1-foot and 4-feet earth. The tube of the maximum was liable to slip, so I fixed it with a piece of cork. The sunshine recorder does not get the early morning and the late evening sun. The trees on the east side make an angle of 8°. It is difficult to get a good exposure, as the place is very much wooded.

WORTHING, *July* 17.—The instruments are placed in an open grass space on the north side of the Public Library. The thermometers required rearranging in the screen. Both the Campbell-Stokes and Jordan sunshine recorders are mounted on the roof of the Public Library. The Campbell-Stokes recorder (universal pattern) was not in proper adjustment, the ball being too high. This I readjusted. The Water Inspector takes the temperature and rainfall observations, and the Curator of the Public Library attends to the sunshine recorders. These officials are under the Town Surveyor, but Dr. Kelly has the general supervision.

APPENDIX III.

OBITUARY NOTICES.

WILLIAM GEORGE, the first BARON ARMSTRONG, was the son of Mr. W. Armstrong, a merchant and prominent citizen of Newcastle-on-Tyne, and was born on November 26, 1810. Educated at a school at Bishop Auckland, he resolved to adopt the Law as his profession, and entered a solicitor's office. But though in course of time he became a partner in the firm of Donkin, Stable, and Armstrong, his heart was never in his work. His inclinations were all for scientific pursuits, and in these he indulged to such good purpose that some years before he definitely gave up the practice of the law he had made several of the inventions with which his name is associated. To most men he is doubtless chiefly known as a maker of big cannon and other munitions of war, for that is the side of his work which appeals most strongly to the popular imagination. But his services to the art of war do not form his only title to remembrance. Engineers know him in connection with a system of hydraulic transmission of power which lends itself to a wide range of useful applications; while his inquiries concerning the probable duration of the coal under our soil, and his condemnation of the reckless and wasteful manner in which it is consumed, have at least merited serious attention in a country whose prosperity mainly depends on its continued supply of cheap fuel.

In most of the great developments which have characterised the art of gunnery during the last forty or fifty years England has led the world, and Lord Armstrong may be said to have led England. He was in fact the inventor of modern artillery and the first to apply in practice the principles which now almost universally govern the manufacture of heavy ordnance. When he came on the scene a gun was little better than a block of metal with a hole bored down its centre, not accurate enough in shooting to utilise long ranges and high velocities, and not strong enough to stand the charges necessary to produce them. He transformed it into a nicely articulated structure put together with exact regard for the various strains which each portion is called upon to bear under the enormous forces liberated by the burning of the powder, while rifled barrels and elongated projectiles gave to the shooting of his earliest guns an accuracy which was never attained before and has scarcely been surpassed since. Nor are his services to the science of gunnery limited to the improvements suggested by his own inventive genius. The great works at Elswick, which he established originally for the manufacture of hydraulic machinery, have proved a veritable nursery of military inventions.

He was appointed Engineer of Rifled Ordnance, being made C.B., and receiving the honour of knighthood. Under his supervision some 3500 of these guns were turned out between 1859 and 1863, and England became the possessor of the best armament then in existence.

About 1863, Sir W. Armstrong gave up his official position and devoted his energies to the Elswick works, which, under his care, gained a world-wide reputation for the manufacture of warlike material.

To Lord Armstrong the world is indebted for the development of the hydraulic machinery which to-day plays so important a part in the business of our docks and large railway stations.

In awarding the Albert Medal to Lord Armstrong in 1873, the Society of Arts recognised the benefits which have accrued to manufactures through his development of the hydraulic transmission of power.

In the address he delivered as President of the British Association at Newcastle in 1863, he brought forward some calculations as to the amount of coal in our coalfields and the time it might be expected to last. He pointed out how rapidly we are consuming those seams from which coal can be taken of such a quality and at such a price as to enable us to maintain our supremacy in manufacturing industry.

Lord Armstrong was the inventor of a form of electrical machine which at one time attracted a good deal of attention. In later years Lord Armstrong was an occasional exhibitor of electrical experiments at the *conversazioni* of the Royal Society (of which he became a Fellow in 1846), and it was in his 87th year that he published an elaborately illustrated book on *Electric Movement in Air and Water*, which discussed and amplified a striking experiment he had performed more than half a century before.

Many honours fell to his lot. Cambridge made him a LL.D. in 1862, and Oxford a D.C.L. in 1870. The Civil Engineers chose him to be their president in 1882, and he more than once served the same office for the Mechanical Engineers. An original member of the Iron and Steel Institute, he was in 1891 awarded the Bessemer Medal by that

body, and a large number of foreign decorations which were bestowed upon him attested the reputation which his work won for him abroad. At the general election of 1886 he unsuccessfully contested Newcastle in the Unionist interest against Mr. John Morley, but in the following year Lord Salisbury enabled Armstrong to enter Parliament in another capacity by advising her late Majesty the Queen to raise him to the peerage. Apart from the substantial advantages that must accrue from the existence of a huge industrial establishment like Elswick in its neighbourhood, his native city had to thank him for the gift of several public buildings and parks. Among the latter was Jesmond Dene, where at one time he resided. In 1863 he acquired the rocky ravine near Rothbury, where he built Cragside, the handsome Elizabethan mansion in which he died, and he was also the owner of the old fortress of Bamborough Castle, in the restoration of which he took an active part and interest when he had already entered on his ninth decade. By his death Newcastle has lost her greatest citizen, and the country at large one of the worthies of the expiring century.

Lord Armstrong died on December 27, 1900.

He was elected a Fellow of this Society on March 24, 1857.

CHARLES COPPOCK studied at Queen's College, Cork, with the intention of following the profession of a Civil Engineer. He, however, eventually entered the firm of Messrs. R. and J. Beck, scientific instrument makers, of Cornhill, London, with whom he was associated for many years. Subsequently he carried on business on his own account in Mount Street, Grosvenor Square. He owed much of his early scientific training to his uncle, Professor Smith, whose work upon Diatomaceæ is well known to microscopists.

Mr. Coppock was one of those who study science as a recreation. The microscope was his favourite instrument, both from a mechanical and a scientific point of view.

He died on September 5, 1900.

He was elected a Fellow of this Society on April 20, 1864.

SOMERSET BARRY, the tenth BARON FARNHAM, who died on November 22, 1900, was born at Newtown Barry, Co. Wexford, March 7, 1849. His father was the Hon. Richard, and the subject of the present notice succeeded his uncle James in the title in 1896. He married, in 1875, Lady Florence Jane Taylour, daughter of the Marquis of Headfort, and has left several children.

In early life he had been in the army, and had reached the rank of Captain in the Royal Irish Fusiliers. At the time of the Land League agitation in Ireland he took a very leading part in the organisation and maintenance of the Property Defence Association and in the Landowners' Convention. In 1881 he headed a party of Ulster labourers who went down to Galway to aid Captain Boycott and others in resisting the League.

He devoted himself largely to scientific pursuits, more especially to microscopy and astronomy, and had a small but very complete observatory, containing a Grubb 6-inch equatorial and accessories, fitted up at Arley Cottage, on the banks of Lough Sheelin, where he resided until he succeeded to the title in 1896.

In order to ensure the best observing conditions, his observatory was established at some little distance from the dwelling-house, but no considerations of inconvenience or fatigue deterred him from the systematic pursuit of his astronomical labours. He collected a considerable number of double-star measures, and calculated the orbits himself.

He was anxious to help fellow-workers, and will long and gratefully be remembered by many in the north of Ireland for the prominent part he took in the organising and carrying on of the Ulster Astronomical Society, established in 1890. He was Vice-President of that Society (the President being the Rev. Dr. Hamilton, President of Queen's College, Belfast). He delivered many valuable lectures in connection with the Ulster Society.

In 1891 he equipped a meteorological station, and his observations were for some years published by the Meteorological Office.

On succeeding to the title he removed his residence to Farnham Castle, near Cavan, but up to the time of his death had not resumed meteorological work.

He was a representative peer for Ireland, and also Grand Master of the Orange Association.

He had received a terrible shock in 1898 by the death, from a bicycle accident, of his eldest son, who had only just attained his majority. The title has therefore descended to his second son, Arthur Kenlis.

Lord Farnham was a universal favourite.

He was elected a Fellow of this Society on November 19, 1890.

Rogers Field, eldest son of Mr. Edwin Wilkins Field, solicitor, of London, was born in 1831, and was educated at University College School and University College, Gower Street, and graduated B.A. London. He was articled in 1853 to Mr. Thomas Wicksteed, under whom he was engaged on the Leicester sewerage and the Scarborough waterworks. From 1859 to 1864 he was employed on drainage and reclamation works for Mr. Bailey Denton; and since the latter year he was in practice in Westminster—at first alone, and latterly in partnership with Mr. A. T. Bean—as a Hydraulic and Drainage Engineer.

Mr. Field's work was characterised by thoroughness and attention to detail; the science and practice of hydraulics had a peculiar fascination for him, and he was never so happy as when making, in the experimental laboratory attached to his offices, hydraulic investigations involving minute accuracy. He devoted himself with great energy to the practical application of the principles governing the sanitation of buildings, and did much to raise this important subject to a scientific level. The by-laws and regulations for house drainage framed by him in 1876 for the town of Uppingham were among the first of the kind; they attracted considerable attention, and were substantially adopted by the Local Government Board in their model by-laws of 1877 as to house drainage.

Mr. Field designed and superintended the construction of the water-supply, drainage, and sewage disposal arrangements of a number of public institutions, hospitals, asylums, schools, and private residences throughout the country, including the drainage of Sandringham House and Bagshot Park. He was interested in the question of the drainage of agricultural land, and also in that of sewage disposal, and was in

favour of sewage purification by application to land wherever practicable, by broad irrigation either over porous land or over specially prepared filtration-areas well underdrained. He was the inventor of Field's engineering aneroid-barometer, having an adjustable scale which takes into account the variable temperature of the air. The principle of adjustment is that of shifting the altitude-scale according to the temperature of the air; and the scale having been set according to the temperature likely to prevail during the observations, it will be found that the readings will give at once the differences of elevation with great accuracy. In all questions relating to meteorology he was particularly interested, and paid much attention to rainfall, evaporation, and percolation, and the movement of underground water, on which he contributed some valuable chapters to a work entitled *Our Homes, and how to make them Healthy*, published in 1883. He drew up in 1892 a pamphlet issued by the Commissioners in Lunacy, entitled *Practical Suggestions as to Water-Supply, Drainage, and Sewage Disposal for Lunatic Asylums*, as a guide to engineers and surveyors having to deal with such matters.

Rogers Field carried out an extensive series of experiments on the working of siphons, resulting in the particular form of annular self-acting siphon which he invented and brought to a high standard of perfection. These siphons have, from their trustworthiness in action, been very extensively used for flushing purposes in drainage and sewerage works in this country, and also in many places abroad, particularly in America, where they have been adopted in conjunction with the Waring system of sewage disposal for isolated establishments by means of a siphon tank and sub-irrigation drains.

Mr. Field took great interest in the Parkes Museum of Hygiene and the Sanitary Institute, of the Council of which body he was an active member. For many years he was engaged in carrying out for that Institute an exhaustive series of experiments on air-meters, cowls, and terminals. He was one of the Judges at the International Medical and Sanitary Exhibition of 1881, and was on the Committee of the International Health Exhibition of 1884, and prepared the sections of the *Handbook on the Water-Supply and Disposal of Sewage of Country Houses*, published by the Executive Council of that Exhibition.

Mr. Field died at his residence, Squire's Mount, Hampstead, on March 28, 1900, aged 68.

He was a Member of the Institution of Civil Engineers.

Mr. Field was elected a Fellow of this Society on February 15, 1865, and he served on the Council 1872-83, being Vice-President 1875-76 and 1882-83.

HENRY LAW was born at Reading on April 15, 1824. At an early age he was sent to school at Hackney, but trouble with his eyes necessitated his leaving school when only eight years old. Three separate operations for cataract were performed, but the sight of one eye was never recovered. At ten years of age he went to school again, remaining there until he was thirteen, and during that time he made several mechanical models and drawings. These were brought to the notice of Sir Isambard Brunel, who took Henry Law into his office for two months, and subsequently gave him articles as a pupil. He was then placed on the

Thames Tunnel staff, and remained on those works until their completion in 1843.

He was next employed by Mr. Thomas Page, who had been chief of the Thames Tunnel engineering staff, to assist in taking soundings and in making surveys of the river Thames. In 1844 Mr. Page became Engineer to the Commissioners of Woods and Forests, and Mr. Law entered his office as an assistant. In that capacity Mr. Law assisted in the design and survey of several works connected with the Thames, and acted as Resident Engineer for the Windsor Improvements, including the Victoria and Albert Bridges, finally leaving Mr. Page in 1850.

In 1852 Mr. Law began to practise on his own account, and in 1853 was joined in partnership by Mr. John Blount. He erected three bridges over the river Wye, and also spent some time in Portugal with Mr. Thomas Rumball, making surveys for the Central Peninsular Railway. In 1855 he went to Rio de Janeiro to report on a proposal to construct a slip at Bahia. This brought other work, and he remained in Brazil until 1863, carrying out a number of important works there, among which may be mentioned the Ilha das Cobras Dock, Bahia Gasworks, Ceara Gasworks, and Pernambuco Drainage. He returned to England in 1865, but made several visits to Brazil until 1875, when he once more settled down to practise in England.

In 1878 he entered into partnership with Mr. George Chatterton, and the connection lasted until 1887. Mr. Law, as senior partner in the firm of Law and Chatterton, enjoyed a large practice as a consulting engineer, and was employed by the late Metropolitan Board of Works to act in conjunction with their engineer, the late Sir Joseph Bazalgette, on most of their Parliamentary Bills. He was engaged in the long series of inquiries which finally resulted in the freeing from toll of all the metropolitan bridges. He was also engaged on the Thames Flood Prevention Bills, and in both the protracted inquiries dealing with the discharge of the London sewage into the Thames at Barking and at Crossness. After the Tay Bridge disaster he was instructed by the Government to report fully on the cause of the accident, and in 1892 he was appointed by the Foreign Office to consider, with German and French colleagues, the various schemes for the drainage of Cairo submitted to the Egyptian Government.

During Mr. Law's long and varied career he was associated with many works in various parts of England, but for some years past he was more intimately concerned with works of sanitation, his latest being the drainage of Oldham and Broadstairs, and the prevention of flooding at Eastbourne. Mr. Law possessed mathematical powers of a high order, and his calculations were most refined and accurate. He was of a very inventive turn of mind, and devised for his own use, among other things, an electrical sounding apparatus and an electrical current meter. He was the author of several mathematical and engineering books, among which may be mentioned *Examples of the Modes of Setting-out Railway Curves; Mathematical Tables for Trigonometrical, Astronomical, and Nautical Calculations; The Rudiments of Civil Engineering;* and *The Art of Constructing Common Roads.* Mr. Law took great interest in the Sanitary Institute, of which he was for many years a Member of Council, and at the time of his death Chairman of Council.

Mr. Law died at his residence in London on July 18, 1900, having just attained his 76th year.

He was a Member of the Institution of Civil Engineers, and also a Fellow of other Societies.

He was elected a Fellow of this Society on June 20, 1877.

Sir John Bennet Lawes, Bart., was born in 1814, and was the son of the late Mr. John Bennet Lawes, of Rothamsted, Herts, who died in 1822. He was educated at Eton, and afterwards at Brasenose College, Oxford, where he went in 1832 for a period of three years. As his inclinations were scientific rather than classical, his earlier studies had little direct bearing upon his future career. Before he reached the age of 20, however, he had acquired an intimate knowledge of the British Pharmacopœia. Succeeding to the paternal estates in 1834, he amused himself by sowing on his farm poppies, hemlock, henbane, belladonna, and other plants, the active principles of which were at that time coming to be better understood. Farmers were then suffering from the abundance of crops, and wheat, in spite of a rigid policy of protection, was at a very low value, the annual average price per quarter having been 46s. 2d. in 1834 and only 39s. 4d. in 1835. Having at that time the home farm of 250 acres in hand, Mr. Lawes commenced a series of experiments with the view of obtaining explanations of certain imperfectly understood points in agriculture. Accordingly, in 1837 and the two following years, tests were made of the effects of various manures upon plants growing in pots, and the beneficial results following the manuring of turnips with phosphates that had been treated with sulphuric acid were then for the first time observed. In 1840 and 1841 similar experiments were conducted in the field, the upshot of which was that in 1842 a patent taken out for treating mineral phosphates with sulphuric acid marked the beginning of the manufacture of artificial manures, an industry which has since attained enormous dimensions. In 1843 a young chemist, Dr. (now Sir) J. Henry Gilbert, a former pupil of Liebig, became associated with Mr. Lawes, and the foundation of the Rothamsted Agricultural Experiment Station dates from that year.

To indicate ever so briefly the scope of the investigations which have been successfully conducted at Rothamsted would be, in effect, to summarise the history of the progress of agricultural chemistry during the last half-century. Two main lines of inquiry have been followed, the one relating to farm crops and the other to farm animals. In the field experiments the method adopted has been to grow some of the most important rotation crops (wheat, barley, oats, beans, clover, roots, potatoes), each separately, year after year, for many years in succession on the same land without manure, with farmyard manure, and with a great variety of chemical manures, the same kind of manure being as a rule applied year after year on the same plot. Experiments on an actual course of rotation, without manure, and with different manures, have also been made.

The experiments on cattle, sheep, and pigs dealt with the quantity of food consumed in relation to a given live weight of animal in a given time; the quantity consumed to produce a given amount of increase in live weight; the proportion, and relative development, of the different

organs or parts of animals; the composition of the animals in different conditions as to age and fatness; the composition of the manure in relation to that of the food consumed; the yield of milk in relation to the food required to produce it; and the influence of different descriptions of food on the quantity and on the composition of the milk. Incidentally there came up for consideration such important questions as the sources in the food of the fat produced in the animal body, the characteristic demands for nitrogenous or non-nitrogenous constituents of food in the exercise of muscular power, and the comparative characters of animal and vegetable foods in human dietaries.

In his brochure on *Fertility*, published in 1881, Sir John Lawes stereotyped the views which he had enunciated twenty years previously, and thereby added much to the difficulty of modifying his opinions at a subsequent date. The 70 pages of this masterly pamphlet all pointed to one conclusion—that the soil is a mine and not a laboratory. It is a matter of regret that Sir John Lawes did not find an opportunity of rewriting his essay on *Fertility* in the light of the fuller knowledge since attained of the micro-organisms of the soil.

Most of the results of the Rothamsted experiments have been given to the world through the medium of the *Journal of the Royal Agricultural Society*, from the year 1847 onwards, though many other serial publications were utilised for the purpose. About 130 separate memoirs or papers have been published. From the year 1862 onwards Sir John Lawes sent to *The Times* every October an estimate of the yield of the wheat crop of the United Kingdom for the current season.

Sir John Lawes took a cordial interest in the welfare of the Royal Agricultural Society, of which he was elected a member in 1846. He had occupied a seat on the Council since 1848, was elected a Vice-President and Governor in 1878, and a Trustee in 1891. When, at about the time of the jubilee of the Rothamsted experiments, he was offered by the Council the highest honour in its power to bestow, he pleaded advancing years and increasing deafness as reasons for not succeeding to the office of President of the Society. He took an active part in 1876 in the establishment of the Society's experimental farm at Woburn, rendered possible by the generosity of the Duke of Bedford, and frequently paid visits of inspection in order to note the progress of the investigations and to compare the results with those obtained at Rothamsted.

In 1854 he was elected a Fellow of the Royal Society, and in 1867 was awarded, jointly with Dr. (now Sir Henry) Gilbert, the Royal Medal. In 1877 the University of Edinburgh conferred upon him the honorary degree of LL.D., and in 1894 the University of Cambridge the degree of D.Sc. In 1882 he was created a baronet. As long ago as 1854 the national importance of the work he was carrying out induced the agriculturists of the country to raise a public subscription for the presentation of a testimonial to Mr. Lawes, which at his suggestion took the form of a well-built laboratory, in which most of the chemical work relating to the investigations has been conducted. It was within the shadow of this laboratory that, in July 1893, a large gathering of agriculturists and scientific men, representatives of many countries, assembled to celebrate the jubilee of the Rothamsted experiments.

Numerous congratulatory addresses were read, and Sir John Lawes was presented with his portrait, painted for the subscribers by Mr. Herkomer, R.A.; whilst, facing Harpenden Common, a granite memorial was erected to commemorate the completion of fifty years of continuous experiments (the first of their kind) in agriculture, conducted at Rothamsted."

Sir John Lawes was one of the greatest benefactors of agriculture—perhaps the greatest—the world has seen. His originality in experimental research and his inflexibility of purpose, coupled with a genius of no ordinary kind, enabled him to discover grand truths which have had a profound influence upon the progress of agriculture. Happily, through the munificence of their founder, the Rothamsted experiments do not cease at his death. By a trust deed, executed in 1889, Sir John Lawes set apart a sum of £100,000, together with the laboratory and certain areas of land, for the prosecution of the investigations in perpetuity. The unique feature of the work at Rothamsted—its long unbroken continuity—will thus be characteristic of it in an ever-increasing degree.

Sir John Lawes died on August 31, 1900, the cause of death being an attack of dysentery.

He was elected a Fellow of this Society on June 15, 1864.

Edward Joseph Lowe was the only surviving son of the late Mr. Alfred Lowe, of Highfield House, Nottingham, where he was born on November 11, 1825. At the age of 15 he began an important series of meteorological observations, which were continued down to the time of his removal (in 1882) to Chepstow, Monmouthshire. He published in 1846 *A Treatise on Atmospheric Phenomena*, and two years later began to assist the late Prof. Baden-Powell, of Oxford, in his work on luminous meteors, and the results of their observations, which extended over a number of years, were communicated to the British Association.

Mr. Lowe wrote several papers on meteors and fireballs in *Recreative Science* and other publications. He observed the eclipse of 1860 at Fuente del Mar, near Santander, making a very complete series of meteorological observations which showed the temperatures at various heights above the ground, amount of cloud, amount of light, etc., during the eclipse. His activities extended to other branches of science. In the Royal Society's *Catalogue of Scientific Papers* is a list of forty-six papers by him (up to 1883) on a great variety of subjects. He invented the dry-powder tests for ozone in the atmosphere; he was an ardent naturalist, publishing works on conchology, on British ferns, grasses, and plants. His experiments on the hybridisation of ferns produced some remarkable results, which, however, were not generally accepted as final.

He died at his residence, Shirenewton Hall, Monmouthshire, on March 10, 1900.

Mr. Lowe was elected a Fellow of the Royal Society, and was also a Fellow of several other scientific Societies.

He was one of the original members of this Society, being present at the first meeting on April 3, 1850, and he served on the Council 1851-53.

John M'Landsborough was the eldest son of Andrew M'Landsborough, of Kells, in Scotland, who had settled at Otley, in Yorkshire,

where his son was born on May 3, 1820. Young M'Landsborough was educated in Otley, principally in the grammar school of that town. He was apprenticed to a currier and leather merchant, but after completing his indentures, finding the occupation uncongenial, he obtained employment on the Ordnance Survey, and soon became an expert surveyor. Desiring to be a civil engineer, he spent several years with the late Mr. John Miller, a civil engineer, in Edinburgh, and returning to Yorkshire he commenced practice in Bradford in 1850. His experience in Scotland had been chiefly in connection with the laying-out and construction of railways, and he did similar work in his general practice at Bradford. Besides work for other companies, he was instrumental in inducing the Midland Railway to extend their line to Otley and Ilkley, and he was engineer for the line between Keighley and Oxenhope. He was also greatly interested in sanitary engineering, and carried out various waterworks undertakings at Shipley, Horsforth, and Clitheroe, besides drainage works at Burley, Yeadon, and many other places.

When quite a young man, Mr. M'Landsborough started a Mutual Improvement Society, afterwards merged in a Mechanics' Institute, of which he became a member of the committee of management. He was always much interested in the institutions of Bradford, and at his death left a fine collection of British minerals and fossils, which he had formed, to the Cartwright Memorial Hall, and about 250 volumes of scientific books to the Central Free Library.

In 1868 he established a meteorological station at Bradford, and commenced a series of daily observations, which are still carried on by Mr. H. A. Johnson, now Mr. M'Landsborough's successor in business. He was one of the original members of the Yorkshire Naturalists' Union, and one of the oldest members of the Yorkshire Geological and Polytechnic Society. He was greatly interested in astronomy, and had for many years a good reflecting telescope mounted at his residence at Manningham near Bradford.

He retired from business in 1882, and continued to reside at Manningham till his death on February 24, 1900, in his eightieth year.

He was elected a Fellow of this Society on March 16, 1860.

William Marcet, M.D., F.R.S., belonged to a family distinguished in science, medicine, and literature. He was the eldest son of Francis Marcet, Professor of Physics in the Academy, now the University, of Geneva, and was the grandson of Dr. Alexander Marcet, Physician to Guy's Hospital, whose wife was the well-known authoress Jane Marcet. His family belonged to Geneva, where William Marcet was born in 1828, and received his early education at the Geneva Academy, proceeding to Edinburgh in 1846 for the purpose of studying medicine. At Edinburgh he was the contemporary and friend of Murchison, Burdon-Sanderson, and Priestley, who have all occupied such distinguished positions in the medical profession in this country. He took his doctor's degree with high honours in 1850, and left Edinburgh for Paris, where he worked in the chemical laboratory of Prof. Verdeil, in collaboration with whom he presented various communications to the Biological Society of Paris. Leaving Paris in 1853, he settled in London, and was shortly afterwards appointed Assistant Physician to the Westminster Hospital

(1855), and in 1857 was elected a Fellow of the Royal Society, in recognition of the value of his work in Physiological Chemistry—mainly researches into the chemistry of digestion, and the action of alcohol on the body.

Dr. Marcet became a Fellow of the Royal College of Physicians in 1859, Examiner 1862-67, Councillor in 1871-72, and was appointed Croonian Lecturer in 1895.

Scientific research had always greater attraction for him than the practice of medicine, and he resigned his post at the Westminster Hospital in 1863, but joined the staff of the Brompton Hospital in 1867, at a time when he was greatly interested in the study of tubercle. In this year, 1867, he published a pamphlet confirming Villemin's experiments on the inoculation of tubercle in animals, and began to study the effects of climate on phthisis and other diseases, publishing a work on *The Principal Southern and Swiss Health Resorts* in 1883.

In conjunction with his friends Burdon-Sanderson, Murchison, and Bristowe, he took part in the scientific inquiry made at the request of the Royal Commissioners on the Cattle Plague, and reported on the chemistry of the blood and tissues in that disease (1866).

Dr. Marcet resigned his post at the Brompton Hospital in 1871, and from that period he may be said to have devoted himself to scientific research, especially to the phenomena of human respiration. Possessed of ample means, he spared neither expense nor labour in carrying out his experiments; they were conducted not only in the laboratory, but also by observations made on the effects of temperature, high altitudes, muscular exertion, and volition on the respiration.

The analysis and laboratory work connected with his researches were carried out for the most part in a laboratory at University College, lent to him by Prof. Schäfer; but his observations were conducted in various localities, and frequently at very high altitudes: on the Breithorn at 13,685 ft.; the Col Théodule, 10,899 ft.; the Col de Géant, 11,030 ft. The cold experienced at these heights in the Alps introducing a disturbing element on the effects of atmospheric pressure, Dr. Marcet spent in 1878 three weeks on the Peak of Teneriffe at a height of 13,000 ft., where the temperature is not nearly so low as on the Alps at a similar elevation. The results of these years of observation were brought before the Royal College of Physicians in the Croonian Lectures (1895), which he afterwards published, together with a supplement detailing *The Methods of Investigation and Analytical Results*, and form a most important contribution to the physiology of the respiration. In the course of his experiments Dr. Marcet devised a new form of eudiometer, for measuring the percentage of oxygen in expired air; and he also brought before the Royal Society a modified calorimeter, for more accurately measuring the heat given off by the body.

Besides the papers he communicated to the Royal Society, Dr. Marcet contributed two papers to the Royal Medical and Chirurgical Society on Laryngeal Phthisis, and numerous papers to other scientific and medical societies.

Dr. Marcet was a prominent member of the Alpine and Swiss Alpine Clubs, and an enthusiastic lover of the Alps and mountain scenery, which he enjoyed to the full at his Swiss home on the Lake of Geneva. Dr

Marcet had for many years been a sufferer from asthma, and for some years other symptoms of failing health had manifested themselves; but up to the end of his life he retained his youthful energy and spirits, and his death at Luxor on March 4, 1900, whilst on an excursion up the Nile, came as a surprise to those who were only slightly acquainted with him.

Dr. Marcet was elected a Fellow of this Society on November 15, 1876. He served on the Council from 1882 to 1894, and was President 1888-89.

EDWARD PRITCHARD was born at Wrexham on September 13, 1838. His early professional life was spent in survey and railway work in this country and in Australia. In 1865 he became Borough Surveyor of Clitheroe, and held that post until June 1870, when he was appointed Borough Surveyor to the Corporation of Warwick. There he induced the Corporation to adopt his scheme for a sewage-farm, and at the same time a joint Drainage Committee for the districts draining into the river Tame was formed. He also took in hand the provision of a water-supply for Warwick, by which the water was brought by gravitation from Haseley Brook, near Haseley Mill, and which was successfully carried out. The Warwick and Leamington Tramway was also laid down by Mr. Pritchard. At Clitheroe and at Leigh he had organised volunteer fire brigades, of which he acted as captain. Soon after he took up his residence at Warwick he became lieutenant of the Volunteer Fire Brigade there, and in that capacity was present at the great fire at Warwick Castle in December 1871.

In 1876 Mr. Pritchard resigned his appointment at Warwick and commenced independent practice, with offices in Birmingham and in London. Over a hundred towns in Great Britain have been provided by him with waterworks, sewerage, or tramways.

In August 1888 he went to South Africa, to report for the municipality of Cape Town on the best means of sewering the district and disposing of its sewage. This led to his being retained by the municipalities of Woodstock, Claremont, and Wynberg, important districts closely adjoining Cape Town. While waiting for surveys to be completed at Cape Town, he visited the diamond-fields of Kimberley and the gold-fields of the Transvaal. At Kimberley he was able to give some important advice to the authorities on the question of sewage disposal; and at Johannesburg, then just rising into importance, he received instructions to prepare a scheme which should supply water for gold-washing at the mines, as well as for domestic purposes in the town. The waterworks which supply the town of Pretoria were designed by him, and the fittings were sent from this country under his supervision. A water company at Klerksdorp also carried out, under his advice, a scheme for supplying the town from a point in the Vaal River eight miles distant.

Mr. Pritchard was a member of the Institution of Civil Engineers, and also a member of the Incorporated Association of Municipal and County Engineers, of which body he acted as President in 1879-80. He was a Fellow of several other scientific Societies.

He died at his residence in Birmingham on May 11, 1900.

He was elected a Fellow of this Society on March 16, 1898.

WILLIAM TUCKER RADFORD was born at Exeter on November 21, 1810, and was the elder son of Mr. Peter Radford, a physician con-

nected with the Devon and Exeter Hospital. He was sent to Dr. Carpenter's School at Bristol, and later he went to Dublin, boarding in the house of James Martineau and studying at Trinity College, where he took the degrees of M.B. and M.D. He walked the hospitals, but never practised as a doctor. In 1839 he and his mother (his father having died when he was a child) went to reside with his younger brother at Sidmount, Sidmouth, which continued to be his home until he died on May 19, 1900.

Dr. Radford devoted himself chiefly to the study of science (especially meteorology) and art, spending some months of each year in London and travelling a great deal on the Continent. He visited most of the capitals of Europe and nearly all the principal cathedrals. When at home he devoted much time to microscopic studies, and also worked a great deal with his telescopes, particularly one by Steinheil $4\frac{2}{10}$ ins. diameter, with which he resolved many double stars; but no record of the results of his observations can be found. He collected an extensive and valuable library, which was particularly rich in illustrated works and in books of reference on most subjects. He also had a number of engravings, art photographs, cameos, bronzes, etc.

About thirty years ago he began giving away spectacles to the poor lace-workers of the district, carefully testing their sight. This charity gradually extended to others who were in need, until, when shortly before his death he was obliged, by failing health, to give up seeing any more applicants, he had given away more than 32,000 pairs. He was unmarried. He retained his faculties and his interest in scientific, artistic, and general literature until a very short time before his death, which was sudden at last, from heart failure.

He was elected a Fellow of this Society on June 15, 1864.

THOMAS GLAZEBROOK RYLANDS was born at Warrington on May 24, 1818, and died at his residence, Highfields, Thelwall, Cheshire, on February 14, 1900. He was a wire-manufacturer, ironmaster, etc., but found time to develop an interest in many sciences—entomology, botany, geology, mineralogy, zoology, and, later, astronomy. He was a regular attendant at the meetings of the British Association. He did not publish any astronomical work, though for a number of years he constantly used his equatorial and transit. Several years before his death he vested these instruments in trustees for the benefit of the city of Liverpool. They were originally mounted at the Nautical Academy in Colquitt Street, and when the Corporation erected a Technical Institute they were transferred to suitable mountings on the roof of that building.

In 1893 Mr. Rylands published privately a handsome volume entitled *The Geography of Ptolemy Elucidated* (University Press, Dublin), in which, by careful investigations, he seeks to establish and demonstrate by beautiful diagrams a higher degree of accuracy in Ptolemy's writings than he had been previously credited with.

Mr. Rylands bequeathed to the University Library, Liverpool, a large number of books containing MSS. and early printed works, of which a Catalogue has just been printed at the Liverpool University Press. In the preface to the Catalogue, Principal Dale says: "The collection is the most valuable that we have yet received in any single gift."

He was a good Greek and Latin scholar and an able mathematician, and possessed a fair knowledge of architecture, heraldry, and ancient geography. He was a Justice of the Peace for Warrington, and Mayor of Warrington 1858-59.

He was elected a Fellow of this Society on June 15, 1881.

APPENDIX IV.

BOOKS PURCHASED DURING THE YEAR 1900.

BERGHOLZ, P.—Die Orkane des Fernen Ostens. 8° (1900).

MAUNDER, E. W.—The Royal Observatory, Greenwich: A Glance at its History and Work. 8° (1900).

NEVILLE, J.—Hydraulic Tables, Co-efficients, and Formulæ for finding the Discharge of Water from Orifices, Notches, Weirs, Pipes, and Rivers. 3rd ed. 8° (1875).

YEAR-BOOK OF THE SCIENTIFIC AND LEARNED SOCIETIES of Great Britain and Ireland, 1900. 8° (1900).

APPENDIX V.

DONATIONS RECEIVED DURING THE YEAR 1900.

BOOKS AND PAMPHLETS.

Presented by Societies, Institutions, etc.

ADELAIDE, OBSERVATORY.—Rainfall in South Australia and the Northern Territory during 1897.

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ATHENS, OBSERVATOIRE NATIONAL.—Annales, Tome ii.

BANGALORE, CENTRAL OBSERVATORY.—Meteorology in Mysore, 1899.

BARBADOS, COLONIAL SECRETARY'S OFFICE.—Returns of Rainfall in Barbados, 1900.

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Bucharest, Institut météorologique de Roumanie.—Album climatologique de Roumanie, par C. Hepites—Annales, 1898.—Buletinul lunar al observatiunilor meteorologice, 1899.—Organisation du service météorologique de Roumanie, par C. Hepites.—Régime pluviométrique de Roumanie, par C. Hepites.

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APPENDIX VI.

REPORTS OF OBSERVATORIES, ETC.

THE METEOROLOGICAL OFFICE.—W. N. Shaw, F.R.S., Secretary.

The routine work of the Office has been continued as heretofore. The demand for information on the part of the public has increased; especially for forecasts of weather during the harvest season, which, by direction of the Council, are sent daily to agriculturists, and others, who desire to have them for public use, at the cost of the telegrams only.

The annual volume of *Five Day Means of Hourly Readings of Self-Recording Instruments* at Valencia, Kew, Falmouth, Fort-William, and Aberdeen for 1896 has been issued; that for 1897 is completed and nearly ready for issue. The volume of *Observations at Stations of the Second Order* for 1897 is now issued.

Mean values of all the elements, with extremes of temperature for 30 years, at the telegraphic reporting stations for the six months January to June, were prepared for issue on January 1, 1901, as a supplement to the *Daily Weather Report;* the corresponding values for the remaining six months will be ready shortly, and will be issued on July 1, 1901.

On August 1, 1900, a number of changes were introduced in the *Daily Weather Report,* which had for their main objects the extension of the area for which information is given, and the addition of some particulars as to British stations which send daily information to the Office. From the beginning of the current year, the latter object will be more fully served by including returns sent by post or by telegraph from observers in various parts of the country, to whom the Council are greatly indebted for this assistance. Each day's report now includes a barometric chart for the whole of Europe for the morning of the previous day, with climatic information about a number of selected stations, regarded as being of special importance to travellers.

Moreover, the Council have made temporary provision for the sale at 1d. each of single copies of the *Daily Weather Report* at the Office and at the following terminus railway stations: King's Cross, St. Pancras, Euston, Victoria, and Charing Cross.

In the supplementary information in the *Daily Weather Report,* it is clearly brought out that the observations in the United Kingdom at 8 a.m. are taken at an hour later than the corresponding observations on the Continent. To avoid the inconvenience of reports arriving so late, the Dutch and German Weather Departments have applied to the Council for a special service of observations at 7 a.m. (G.M.T.) at some of the British stations, and the Council have made the necessary arrangements. The additional service has now been in operation since May 1, 1900.

The authorities of the Deutsche Seewarte also solicited the co-operation of the Council in furnishing data with regard to pressure, temperature, and rainfall at four British stations, for a series of charts of ten-day means of pressure and

temperature for practically the whole of the Northern Hemisphere, with the exception of the Pacific Ocean. Commencing with the first ten days of July, these "decadic" charts are now being issued by the Seewarte as a supplement to its *Wetterbericht*, about three weeks after the conclusion of the successive ten-day periods.

By international agreement, simultaneous investigations of the upper air by means of balloons and kites take place in various countries of Europe on the first Thursday in each month. The special circumstances of the case prevent the Council initiating experiments of this character in the British Isles, but ascents of unmanned balloons (*ballons sondes*) have been arranged on the days agreed upon, by Mr. P. Y. Alexander, of the Experimental Works, Bath. In connection with the ascents, Prof. Hergesell, of Strassburg, Chairman of the International Sub-Committee for Aeronautics, requested the co-operation of the Council in the collection of cloud observations for the day preceding and the day following, as well as for the day of each ascent. The following observatories have expressed their willingness to co-operate in this matter: Greenwich, Kew, Oxford, Glasgow, Rousdon, Valencia, Falmouth, Liverpool, Stonyhurst, and Aberdeen. They forward to the Office observations of clouds for the three appropriate days of each month, for transmission to Prof. Hergesell, who undertakes the necessary arrangements for collating the results.

In the autumn the Council issued the English version of the *Report of Proceedings of the St. Petersburg Meeting of the International Committee* in 1899. The most conspicuous feature of the publication is a long report by M. Violle upon the measurement of solar radiation; meteorological work with kites and balloons receives its share of attention, and nearly all subjects of recent meteorological investigation are touched upon.

At the instance of the Council, Mr. C. T. R. Wilson, F.R.S., has been continuing his researches into the phenomena associated with Atmospheric Electricity. A report upon his work will be presented to the Royal Society at the end of January 1901.

It has been publicly announced that the site of the new departments of the National Physical Laboratory will be at Bushey Park, instead of in the Old Deer Park, Richmond, as originally arranged. The Council are, however, glad to have learned that this change of place will not interfere with the continuity of the meteorological records of Kew Observatory, where the instruments belonging to the Council will still be maintained.

In the Marine Department the *Charts illustrating the Weather in the North Atlantic during the winter of* 1898-99, which formed the subject of a paper by the Marine Superintendent at the British Association at Bradford, are now ready for issue, with an introduction and notes, and represent a very striking example of a peculiar type of distribution of atmospheric conditions producing unusual warmth on the east of the Atlantic with unusual cold on the western shores.

The Council have made arrangements for issuing a monthly *Pilot Chart of the Atlantic Ocean and the Mediterranean Sea*, commencing from April 1901. It is intended to make the charts available for issue gratis to captains and officers of the mercantile marine who are on the Office list as observers, and to place them on sale for other members of the same service. In this work the Board of Trade have kindly given their assistance by undertaking the distribution of the charts through the officers of the mercantile marine at certain ports. The charts will also be on sale to the public, through the usual agents of H.M. Stationery Office. The Meteorological Office will receive and transmit to the agents the names of subscribers if desired.—*February* 23, 1901.

ROYAL OBSERVATORY, GREENWICH.—W. H. M. Christie, C.B., M.A., F.R.S., Astronomer-Royal.

A Stevenson screen, with hygrometer, and thermometers for maximum and minimum temperature, has been erected on the Magnetic Pavilion ground near the open stand; the original Stevenson screen being retained in its former position in the Observatory grounds, for comparison of the readings at the two stations. In other respects the observing arrangements are as in the preceding year.

The temperature of the air ranged between 94°·0 on July 16 and 18°·0 on February 9. The yearly mean was 50°·4, being 0°·9 in excess of the average. The monthly mean temperatures were in excess in every month with the exception of February, March, May, and August: in December the excess amounted to 5°·8, in July to 4°·4, and in November to 3°·0. The recorded sunshine in the year amounted to 1505 hours out of the 4459 hours during which the sun was above the horizon, giving a percentage of 33·8. In July the sunshine amounted to 59 per cent of the possible duration.

The rainfall for the year amounted to 22·315 ins., which is nearly the same amount as in 1899, and is 2 ins. below the 50 years' average. Since 1895 the deficiency of rainfall as compared with the average has amounted to 19 ins. The rainiest month in the year was February, with a fall of 3·58 ins., exceeding the average for the month by 2·10 ins.—*April* 3, 1901.

ROYAL OBSERVATORY, EDINBURGH.—Ralph Copeland, Ph.D., F.R.S.E., Astronomer-Royal for Scotland.

The meteorological observations have been carried on by the staff under the same conditions as in former years; the bi-daily readings of the barometer, dry and wet bulb thermometers, and estimates of wind and cloud, and the daily readings of the shaded and exposed maximum and minimum thermometers have been continuous throughout the year. A monthly copy of these readings has been supplied to the Secretary of the Scottish Meteorological Society for the use of the Registrar-General for Scotland, and the monthly means have been published in the Registrar's Reports. The Robinson anemometer and the King's barograph have also been kept in operation without interruption, and the weekly readings of the rock thermometers at the Calton Hill have been continued. In December a Campbell-Stokes sunshine recorder was procured and preparations made for commencing observations of this important meteorological element on January 1, 1901.

An interesting record of the great storm of December 20-21 was secured on the Robinson anemograph. This storm was of altogether exceptional violence. For several days preceding the 20th the weather had been of a stormy character, high winds being prevalent. The maximum hourly velocity was reached about midnight of the 20th. Careful measurement showed that the velocity was not less than 93 miles per hour between 11 p.m. and midnight. For the 3 hours 10.30 p.m. of the 20th to 1.30 a.m. of the 21st the average hourly velocity was 84 miles. During the 24 hours from noon of the 20th to noon of the 21st the average was 59 miles per hour. On the 20th the wind blew the whole day steadily from South-south-west, but changed at midnight, about the time of the culmination of the storm, to South-west, and an hour later to South-west by West, at which it remained up to 8 a.m. of the 21st, when it veered to West by North.—*January* 31, 1901.

National Physical Laboratory (Kew Observatory), Richmond, Surrey. —R. T. Glazebrook, Sc.D., F.R.S., Director; and Charles Chree, Sc.D., F.R.S., Superintendent of Observatory Department.

The several self-recording instruments for the continuous registration of atmospheric pressure, temperature of air and wet-bulb, wind (direction, pressure, and velocity), bright sunshine, and rain have been maintained in regular operation throughout the year, and the standard eye observations for the control of the automatic records have been duly registered. The tabulations of the meteorological traces have been regularly made, and these, as well as copies of the eye observations, with notes of weather, cloud, and sunshine, have been transmitted, as usual, to the Meteorological Office.

Electrograph.—This instrument worked generally in a satisfactory manner during the year. The small glass beaker mentioned in last year's Report is still employed, and by removing the sulphuric acid at regular periods—generally fourteen or fifteen days—the trouble previously experienced with the "setting" of the needle and with the shift of zero has been largely overcome.

Scale-value determinations were made on April 2, July 14, and October 25, and the potential of the battery has been tested weekly. Forty cells only have been employed during the year, giving about 30 volts.

Atmospheric Electricity.—The comparisons of the potential, at the point where the jet from the water-dropper breaks up, and at a fixed station on the Observatory lawn, have been continued, and the observations have been taken since March on every day when possible, excluding Sundays and wet days. The ratios of the "curve" and the "fixed station" readings have been computed for each observation, and these have thrown considerable light upon the action of the self-recording electrometer, especially with reference to its insulation. Some direct experiments have also been made on this point.

Fog and Mist.—The observations of a series of distant objects, referred to in previous Reports, have been continued. A note is taken of the most distant of the selected objects which is visible at each observation hour.

Seismological Observations.—Prof. Milne's "unfelt tremor" pattern of seismograph has been maintained in regular operation throughout the year.

The "disturbance" on January 20 was particularly noticeable. The movement was the largest that has yet been fully recorded at the Observatory, the maximum amplitude being 12·6 seconds of arc. The next largest disturbance was on October 29, with a maximum of 9·5 seconds of arc.

A detailed list of the movements recorded from January 1 to December 31, 1900, was made and sent to Prof. Milne, and will be found in the *Report of the British Association* for 1901, "Seismological Investigations Committee's Report."

The mean temperature for the year was 50°·5, and the extremes ranged from a maximum of 89°·4 on July 16, 19, and 20, to a minimum of 19°·0 on February 8. The highest mean monthly temperature was 66°·9 in July, and the lowest 38°·4 in February. The highest temperature in the sun's rays (black bulb *in vacuo*) was 153° on July 16, and this is the maximum value yet recorded.

The mean percentage of sunshine was 33, which is 4 per cent above the average for past 20 years. The highest percentage was 59 in July, and this is the record value for that month.

The minimum temperature on the ground was 6° on February 8.

The rainfall for the year was 21·865 ins., being 2·20 ins. below the average —the wettest month being January with 2·92 ins., and the driest month September with 0·67 ins. only.—*May* 9, 1901.

RADCLIFFE OBSERVATORY, OXFORD.—Arthur A. Rambaut, M.A., D.Sc., F.R.S., Radcliffe Observer.

The meteorological observations and automatic registrations have been maintained as usual, and the results have been regularly sent, as heretofore, to the Meteorological Office (by daily telegram), the Registrar-General, the local newspapers, and to sanitary and other public authorities on request, as well as some private inquirers.

The five underground platinum resistance thermometers have worked very satisfactorily. The observations obtained with these instruments during the year 1899 have been fully discussed and the results published in the *Transactions of the Royal Society* (vol. 195, pp. 235-258), in a memoir entitled "Underground Temperatures at Oxford in the year 1899, as determined by five Platinum Resistance Thermometers."

The following are the chief characteristics of the weather noted at Oxford in the year 1900:—

The mean reading of the barometer was 29·693 ins., being 0·033 ins. below the mean for the preceding 45 years. The highest reading, 30·435 ins., occurred on March 13; the lowest, 28·269 ins., on February 19: a range of 2·166 ins.

The mean temperature of the air was 50°·0, or 1°·2 above the mean for the preceding 72 years. The maximum in the air reached 89°·6 on July 19; the minima were—in the air, 15°·2 on February 9; and on the grass, 9°·0 on the same date.

The following table shows the differences of the mean monthly temperatures from the corresponding means deduced from the observations of the preceding 72 years:—

	°		°		°
January	+2·4	May	−1·3	September	+1·3
February	−2·0	June	0·0	October	+1·3
March	−3·0	July	+4·9	November	+2·9
April	+1·8	August	−0·2	December	+6·1

Very warm weather was experienced in July, the thermometer in the screen indicating temperatures over 80° on 9 days in the month; whilst the mean of the daily maxima for July 18-25 was 82°·9. The mean maximum for the month of July 1900 (75°·7) has been surpassed during the past 25 years on two occasions only, viz. 76°·9 in August 1899, and 76°·1 in July 1876.

The amount of bright sunshine registered in 1900 by a Campbell-Stokes recorder was 1503 hours, or 54 hours above the average for the previous 20 years. The following table gives the monthly differences from the average:—

	hrs.		hrs.		hrs.
January	+ 6	May	−33	September	+30
February	+ 4	June	−16	October	+28
March	−38	July	+79	November	− 2
April	+15	August	−10	December	− 9

The rainfall in the year amounted to 24·577 ins., or 1·560 ins. below the mean for the preceding 85 years. The monthly differences from the mean are given in the following table:—

	ins.		ins.		ins.
January	+0·420	May	−0·571	September	−2·022
February	+2·630	June	+0·644	October	−0·698
March	−1·030	July	−1·847	November	−0·469
April	−0·832	August	+0·836	December	+1·379

In the month of February rain and snow caused the low levels in the valley of the Thames to be seriously flooded.—*January* 29, 1901.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

March 20, 1901.

Ordinary Meeting.

WILLIAM HENRY DINES, B.A., President, in the Chair.

ROY ANDERSON, 1 Glenfell Terrace, Cheltenham;
PHILOTHEIO PEREIRA D' ANDRADE, Salcete, Portuguese India;
EDWIN BAYLES ATKINSON, Scartho Terrace, Great Grimsby;
Rev. JOHN BUFTON, F.L.S., Bunbury, Western Australia;
JOHN DAVIS, Durban, Natal;
GEORGE GOUGH DIXON, Reefton, New Zealand;
PHILIP HARBORD, J.P., Lamas Hall, Norwich; and
ARTHUR EUGENE M'CLELLAN ROLLAND, Durban, Natal,
were balloted for and duly elected Fellows of the Society.

Dr. HUGH ROBERT MILL, F.R.S.E., gave a Lecture on "CLIMATE AND THE EFFECTS OF CLIMATE," which was illustrated by lantern slides (p. 169).

On the motion of Dr. C. THEODORE WILLIAMS, seconded by Mr. BALDWIN LATHAM, a vote of thanks was passed to Dr. Mill for his Lecture.

April 17, 1901.

Ordinary Meeting.

WILLIAM HENRY DINES, B.A., President, in the Chair.

DAVID BROUNLEES CAMPBELL, 164 Manor Street, Cliftonville, Belfast;
MORITZ IMMISCH, 102 Tollington Park, N.;
OTTO CLAUDE IMMISCH, 102 Tollington Park, N.; and
ROBERT JOSEPH ROBSON, 116 Cazenove Road, N.,
were balloted for and duly elected Fellows of the Society.

The following letter from the Home Secretary was read:—

HOME OFFICE, WHITEHALL,
March 29, 1901.

SIR,—I am commanded by the KING to convey to you hereby His Majesty's thanks for the Loyal and Dutiful Address of the President, Council, and Fellows of the Royal Meteorological Society, expressing their sympathy with His Majesty and the Royal Family on the occasion of the lamented death of Her late Majesty QUEEN VICTORIA.—I am, Sir, your obedient Servant,

CHAS. T. RITCHIE.

THE SECRETARY,
ROYAL METEOROLOGICAL SOCIETY.

The following communications were read:—

1. "THE SPECIAL CHARACTERISTICS OF THE WEATHER OF MARCH 1901." By WILLIAM MARRIOTT, F.R.Met.Soc. (p. 185).

2. "VAPOUR TENSION IN RELATION TO WIND." By RICHARD STRACHAN, F.R.Met.Soc. (p. 197).

MEMORIAL TO THE LATE MR. G. J. SYMONS, F.R.S.

A Meeting of the Subscribers to the SYMONS MEMORIAL FUND was held in the rooms of the Royal Meteorological Society on Tuesday, June 11, 1901; Dr. C. Theodore Williams (Treasurer) in the Chair.

Mr. W. Marriott read the following Report of the Executive Committee:—

"At the invitation of the President of the Royal Meteorological Society, a Meeting was held at the rooms of the Society on May 31, 1900, to consider the question of a Memorial to the late Mr. G. J. SYMONS, F.R.S., the distinguished Meteorologist, and Founder of the British Rainfall Organisation.

"It was resolved unanimously that the Memorial should take the form of a Gold Medal, to be awarded from time to time by the Council of the Royal Meteorological Society for distinguished work in connection with Meteorological Science.

"The Meeting appointed the following Executive Committee to take the necessary steps to raise a Fund for that purpose, viz.:—

Dr. C. THEODORE WILLIAMS.
(President Royal Meteorological Society.)

Mr. F. CAMPBELL BAYARD, LL.M.	Prof. R. MELDOLA, F.R.S.
Mr. R. BENTLEY, F.L.S.	Dr. R. H. SCOTT, F.R.S.
Mr. C. HAWKSLEY, M.Inst.C.E.	Mr. H. SOWERBY WALLIS, F.R.Met.Soc.
Mr. J. HOPKINSON, F.L.S.	Mr. W. WHITAKER, F.R.S.

"At their first meeting the Committee appointed Dr. C. Theodore Williams Treasurer, and Prof. R. Meldola and Mr. W. Marriott Secretaries, of the Fund.

"The Committee issued an invitation to the Fellows and Members of the Societies with which Mr. Symons was associated, to the Rainfall Observers, and to others who have in any way benefited by his advice and assistance, to contribute to the Memorial Fund.

"This invitation has been generously responded to, the amount received being £713 : 14 : 7. It is very gratifying to learn how greatly Mr. Symons was esteemed and his work appreciated; for the subscribers number 323, and the contributions have ranged from £26 : 5s. down to 2s. 6d.

"The Committee on November 29, 1900, purchased £600 Cardiff Corporation Redeemable Stock bearing interest at 3 per cent for £589 : 11s.

"The Committee have adopted the designs by Mr. J. Pinches for the dies of the Medal; the obverse being the head of Mr. Symons, and the reverse the Tower of the Winds at Athens.

"The cost of the dies will be £65. This, with the expenses of printing and postage, makes a total expenditure of £100 : 11 : 3d.

The Stock purchased will be handed over to the Royal Meteorological Society, the interest on the same to be used for the award of future medals; and the balance, £23 : 12 : 4, with the sum of £8 : 11s. dividend on the Stock —making £32 : 3 : 4, will also be handed over to the Society, with a request that the Society will expend the same in awarding the first Medal, if possible, within two years of Mr. Symons' death.

"The Committee recommend that the following conditions be submitted to the Council of the Royal Meteorological Society:—

"1. That the Medal be awarded for distinguished work done in connection with Meteorological Science, irrespective of sex or nationality.

"2. That the Medal be awarded biennially, unless the Council see fit to withhold the award."

After some remarks by the Chairman, it was resolved, on the motion of Dr. A. Buchan, F.R.S., seconded by Mr. E. M. Eaton, and supported by Mr. C. Hawksley and Mr. R. Inwards, that the Report of the Executive Committee be adopted.

Mr. C. Hawksley proposed that the Treasurer be instructed to transfer the whole of the property of the Fund to the Royal Meteorological Society. This proposal was seconded by Mr. R. Bentley, and adopted.

Mr. W. H. Dines, the President, accepted the trust in the name of the Royal Meteorological Society.

On the motion of Sir Erasmus Ommanney, F.R.S., seconded by Dr. H. R. Mill, and supported by Mr. J. Hopkinson, it was resolved that the thanks of the Subscribers be given to the Treasurer, Secretaries, and Executive Committee for their services in connection with the Fund.

CORRESPONDENCE AND NOTES.

Re-constitution of the Meteorological Council.—The Meteorological Council was registered under the Companies Act, 1867, in the year 1891. The limiting number of members of such an association is seven, and this was made up of six Members of Council and a Secretary. The change made on Mr. Scott's retirement in 1900 reduced the number of the Association below that limit, as Mr. Shaw, the Secretary, is a member of the Council.

The Council of the Royal Society has lately reconstructed the Meteorological Council as follows: General Sir R. Strachey (Chairman), Prof. G. H. Darwin, Dr. A. Buchan, and Mr. W. N. Shaw, together with the Hydrographer of the Admiralty, are appointed Directors.

The Earl of Rosse, Mr. J. Y. Buchanan, Mr. W. H. Dines, Mr. R. H. Scott, and Prof. A. Schuster, are appointed the other members of the Association: the first two to serve for five years, the last three for three years. No honorarium is to be paid to these additional members.

Crowing of Pheasants during Thunderstorms.—We have received several communications respecting the note on this subject in the last number of the *Quarterly Journal* (p. 158). We shall, however, only quote from two of them.

Dr. J. Hann, of Vienna, says: "I have myself often observed the fact. There were several peacocks in the garden of a villa which lay close to the Hohe Warte at Ober Döbling here. Sitting at my desk at the open window, my attention was often drawn to a distant thunderstorm by the screaming of the peacocks, even before I myself heard the thunder. It is certainly the case that peacocks take similar notice of other noises. If any loud stamping with a rammer went on in the garden, they screamed at each stroke."

Mr. C. Grover, of Rousdon, Lyme Regis, says: "They are a sure guide as to *distant thunder*, and their hearing must be very acute, as they crow on the least sound. As an instance, I may mention the evening of June 1, 1901, when the sky over the Channel was very black, and distant thunder was heard from 5 to 7 p.m. At every sound the pheasants crowed loudly; and several times when the thunder was very faint, and hardly audible to us, the birds evidently heard it distinctly."

Red Rain, March 10-11, 1901.—Mons. M. Barac, Technical Director of the Petroleum Refining Company, has forwarded a "Report on the Dust which fell with the Rain at Fiume on March 10-11, 1901." He says:—

"As I reside at Fiume, I had the dust which fell on the roofs and windows of the petroleum-works on the night of March 10-11, between 11.15 and 11.45 p.m., carefully collected, and have submitted it to minute analysis. Inasmuch as this fall was generally observed over the greater part of Southern and Central Europe, I have thought that it might be desirable to publish what I have been able to ascertain about it.

"I. *Chemical Analysis.*

	%
Silica	49·49
Iron, Sesquioxide	9·96
Alumina	12·10
Manganese, Peroxide	1·99
Lime	11·46
Magnesia	0·40
Carbonic Acid	8·96
Organic Matter	5·48
Traces of Soda, Sulphuric Acid, Muriatic Acid, and Los	0·16
	100·00

"II. *Microscopic Examination.*—Under the microscope, with a power of 640, the main mass consisted principally of colourless and, in less degree, of coloured particles, of irregular shape, partly angular fragments of crystals, and also mineral particles. In addition there were siliceous skeletons of micro-organisms, and, finally, particles of soot. There were a few well-formed rhombohedra of calcite and cubes of common salt; and both the calcite and the quartz crystals exhibited chromatic polarisation.

"As regards magnitude, the minimum was 0·001 mm., the average 0·017 mm., and the maximum among the crystalline particles 0·051 mm.; while the yellow structureless mineral particles attained the size of 0·113 mm.

"Under treatment with muriatic acid, the calcite and most of the iron and alumina compounds went into solution; when the ferrocyanide of potash was employed the corresponding portions of the liquid took a blue colour.

"If we compare these analytical and microscopical results with those given by Baron A. E. Nordenskiold in the *Meteorologische Zeitschrift*, vol ii. p. 201, of his examination of the dust which fell on March 3, 1892, in Sweden and the adjacent countries, we shall hardly be able to avoid coming to the conclusion that we have met with a substance which agrees in its main characteristics with Trade-wind dust.

"If we adopt this idea we have next to calculate what quantity of this dust may have fallen over the entire area which was affected by the fall. In answering this question we must first point out that as the dust fell during rain a considerable quantity of it must have been washed by the rain off the surfaces from which our material was collected. It is apparent that although the dust was carefully removed from these collecting surfaces by camel-hair brushes we only obtained a portion of the total quantity which actually came down."

The author then proceeds to a calculation of the possible amount of dust which must have fallen over the whole area where the red rain was observed.

The paper winds up with the statement that the dust was so fine that it passed almost entirely through a thick linen cloth.

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AN ACCOUNT OF THE BEQUEST OF GEORGE JAMES SYMONS, F.R.S., TO THE ROYAL METEOROLOGICAL SOCIETY.

BY WILLIAM MARRIOTT, F.R.Met.Soc.,
Assistant-Secretary.

[Read May 15, 1901.]

THE Council have requested me to prepare some account of the books and pamphlets in the Symons' Bequest, as they considered that this would give a much better idea of this noble legacy than any mere list of titles.

Mr. Symons, in his Will, dated September 30, 1898, said:—

"I direct that my Cross of the Legion of Honour, my Albert Medal, and such other of my medals and decorations as the President for the time being of the Royal Meteorological Society shall select, shall be fastened inside the case of the album presented to me by the Fellows of the Royal Meteorological Society, and that such album, cross, medal or medals, decorations, and case shall then be delivered up to the President or one of the Vice-Presidents for the time being of the said Society as a present to the same Society, to which Society I bequeath the same accordingly, free of Legacy Duty."

After making over his books relating to Rainfall, etc. to Mr. Wallis, he proceeded:—

"And subject to the bequest to the said Herbert Sowerby Wallis lastly hereinbefore contained, I bequeath to the Royal Meteorological Society such of my books, pamphlets, maps, and photographs as the President for the time being of the said Society shall select, and of which no copy shall then already belong to the said Society and form part of their library. And the same shall be delivered to the said President, or one of the said Vice-Presidents, whose receipt shall be a sufficient discharge for all bequests hereby made to the said Society."

Mr. Wallis generously yielded his prior claim to certain books so as to make the Society's library as complete as possible.

There is also a codicil to the Will, bearing the same date, in which Mr. Symons said:—

"I bequeath to the Royal Meteorological Society the sum of Two Hundred Pounds in addition to the legacies given to them by my said Will, and to be paid exclusively out of such part of my personal estate as may be lawfully bequeathed for charitable purposes, and the receipt of the Treasurer for the time being of the said Society shall be a sufficient discharge for the same. And in all other respects I confirm my said Will."

Album and Medals.

The Testimonial Album which was presented to Mr. Symons at the Meeting of this Society on February 19, 1879, and which contains nearly 200 photographs of the Fellows, bears the following illuminated address:—

TO

GEORGE JAMES SYMONS, F.R.S.

19th Feby. 1879.

PRESENTED BY A LARGE NUMBER OF FELLOWS OF THE METEOROLOGICAL SOCIETY TO

GEORGE JAMES SYMONS, ESQUIRE,

FELLOW OF THE ROYAL SOCIETY, MEMBER OF COUNCIL OF THE ROYAL BOTANIC AND OF THE FRENCH METEOROLOGICAL SOCIETIES, ETC. ETC.,

IN FRIENDLY RECOGNITION OF THE VALUABLE WORK DONE BY HIM FOR THE SOCIETY, BY INSPECTING ITS STATIONS AND TESTING THE INSTRUMENTS USED BY THE OBSERVERS, INDEPENDENTLY OF THE SERVICES RENDERED BY HIM, FOR SEVERAL YEARS, AS ONE OF THEIR SECRETARIES.

The Cross of the Chevalier of the Legion of Honour was conferred on Mr. Symons by the President of the French Republic by decree on May 29, 1891, and that decoration was presented to him by M. Waddington, the French Ambassador in London, on June 18.

Mr. Symons received, on February 26, 1898, from the hands of H.R.H. the Prince of Wales the Albert Gold Medal of the Society of Arts, which had been awarded to him in 1897 "for the services he had rendered to the United Kingdom by affording to engineers engaged in the water supply and the sewage of towns a trustworthy basis for their work, by establishing and carrying on during nearly forty years systematic observations (now at over 3000 stations) of the rainfall of the British Isles, and by recording, tabulating, and graphically indicating the results of these observations in the annual volumes published by himself.

The Silver Medal of the Society of Arts was awarded to Mr. Symons in 1894 for his paper *Rainfall Records in the British Isles.*

Books, Pamphlets, etc.

By direction of the President and Council it became my duty to make the selection of the books, pamphlets, photographs, etc., on behalf of the Society from Mr. Symons' library. This necessitated my attendance at 62 Camden Square daily for a period of about three weeks, as Mr. Symons had about 6500 bound volumes on his shelves, and 7000 or 8000 pamphlets in drawers and cupboards, in addition to a vast number of photographs. As we were only permitted to have such works as were not already in our library, it became necessary to take with me the MS. Catalogue of the Society's Library for frequent reference.

As a result, 2200 bound volumes, about 4000 pamphlets, and 900 photographs were selected on behalf of the Society.

To provide accommodation for such a large number of books, etc., was a serious matter, especially as the new offices of the Society at 70 Victoria Street had only a short time previously been fitted up with bookcases almost to their full capacity. After consultation with the architect, the Council agreed to the fitting up of some more bookcases, drawers, cupboards, and lockers, which would hold this vast addition to the library of the Society. Mr. Symons had evidently thought that something of the kind would be necessary, for the legacy of £200 just met this expenditure.

Mr. Symons' library was almost entirely meteorological, but it included books on subjects closely connected with that science; the subjects embraced may be grouped under the following heads:—

Meteorology.	Earthquakes.	Mineral Springs.
Climate.	Natural Philosophy.	Meteoric Stones.
Electricity.	Physical Geography.	Astronomy.
Magnetism.	Balneology.	Lightning Conductors.

The photographs embrace the following subjects:—

Floods.	Lightning.	Scenery.
Frost.	Meteorological Stations.	Groups.
Snow.	Apparatus.	Miscellaneous.
Whirlwinds.	Instruments.	

In addition to the above, fifty lantern slides were also selected.

Mr. Symons endeavoured to procure a copy of each edition of a work. In selecting the books from his library it became a matter for consideration whether I should choose the first edition, the last edition, or all the editions. After consultation with the President, he advised me to take all the editions, and so follow upon the lines pursued by Mr. Symons. This, I am sure, was the proper course to adopt, as the copies of the various editions will add greatly to the completeness of the Society's Library.

A book-plate bearing a portrait of Mr. Symons (Fig. 1) has been prepared and inserted on the inside of the cover of all the bound volumes, while all the pamphlets, etc., have been stamped with the words "Symons' Bequest."

The cataloguing of the books and pamphlets has not yet been completed, but of those already done it may be interesting to know something

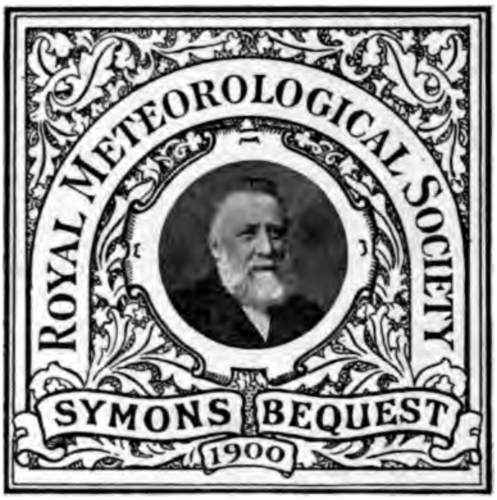


FIG. 1.—Bookplate.

about their dates of publication. By arranging them in centuries we have the following results :—

Century	1476-99	1500-99	1600-99	1700-99	1800-99
No. of Works	9	128	214	403	4256

The books are of various sizes, as will be gathered from the two following extreme examples :—

The largest measures 17½ ins. in length, 12 ins. in width, and 4 ins. in depth—or thickness—and is a fine and rare copy in two volumes of Aristotle's complete works in the original Greek text, accompanied by a Latin translation, arranged in parallel columns by Du Val, printed at Paris, 1619. Mr. Symons apparently purchased this work for the sum of £5 : 15 : 6.

The smallest example is a booklet on "Practical Hypsometry," by Edw. David Hearn, M.A., and measures 2 ins. in width and 1¼ ins. in height, and from cover to cover contains 8 pages. The following is a reproduction of the front of the cover—actual size.

PRACTICAL HYPSOMETRY:
A METHOD OF
DETERMINING ALTITUDES
WITH THE ANEROID BAROMETER,
WITHOUT TABLES.

(*Entered at Stationers' Hall.*)

London: MINING JOURNAL, 26, Fleet-st.
Price One Shilling.

Many of the books have beautiful and elaborate illustrations, not only

in the text but also as frontispieces. They are quite equal to—if they do not surpass, the illustrations of the present day, and they certainly must have been much more expensive. Many of the editions of Aratus have quaint woodcuts illustrative of the various constellations and planets. The same design has not been adhered to throughout, and the characters are not always depicted in the same way: for instance Saturn, who was practically the patron of agriculture, in the edition for 1549 is represented as seated in a chariot, drawn by griffins, and with a scythe in his hand—while in the edition of twenty years later, viz. 1569, he is still represented seated in his chariot, but with a wooden stump, having apparently lost the lower portion of the right leg. The most curious thing is that in a Spanish work entitled *Astronomica Curiosa*, by Leonardo Ferrer, published at Valencia in 1677, Saturn is depicted as a poor agricultural labourer hobbling along with his implements over his right shoulder, and a wooden stump apparently supporting his *left* leg!

These illustrations are reproduced on a reduced scale in Figs. 2, 3, and 4.

FIG. 2.—Saturn (1549).

FIG. 3.—Saturn (1569).

FIG. 4.—Saturn (1677).

Earliest Works.

The nine works published previous to the year 1500 are as follows—

1. ARISTOTLE, AND ALBERTUS MAGNUS. — GAIETANI DE TIENIS IN METHEOROBUM ARISTOTELIS LIBROS EXPOSITIO. ALBERTI MAGNI MINERALIUM LIBRI V. *Patavii*, Impress. per Petr. Maufer., 1476.

The two works are beautifully printed in gothic, and hand rubricated. Bound together in a large folio volume.

2. DIALOGUES (Anonymous).—DYALOGUS CREATURARU OPTIME MORALISATUS.

A quarto pamphlet with hand-tinted illustrations (incomplete) dated 1480.

3. FIRMINUS AND HIPPOCRATES.—1. OPUSCULU REPERTORII PRONOSTICON IN MUTATIONES AERIS, ETC. 2. LIBELLUS DE MEDICORU ASTROLOGIA. *Venetiis*, 1485.

Hand rubricated. Bound together in one 8vo volume.

4. ALLIACUS.—TRACTATUS SUP. LIBROS METHEORORŪ: ARISTOTELIS. 8vo (?).

Published at Leipzig, 1485 or 1500. There are also two other editions of this work in the Bequest, dated respectively 1504 and 1506, the earliest and latest copies being in black letter.

5. ARATUS.—PHAENOMENA. 8vo. *Venetiis*, 1488.

Containing curious old woodcuts.

6. "FLORES ALBUMASARIS." 8vo. 1488.

With numerous woodcuts.

7. ROLEWINCK; OLD CHRONICLE, "FASCICULUS TEMPORUM." Gothic letter. 4to. *Circa*, 1490.

8. BONATUS.—TRACTATUS ASTRONOMIE. 8vo. ? *Venetiis*, 1491.

9. ARATI SOLENSIS PHAENOMENA CVM COMMENTARIIS.

This is an edition in the original Greek, to which Mr. Symons has affixed a note—"an extremely old, if not the earliest edition—excessively rare. De La Lande speaks of it as of 1499, but Buhl quoting Scheibellius, speaks of it as older, *i.e.* as preceding the Aldine edition. De La Lande is evidently referring to this, as he says 'folio wholly Greek, no name or place, and 60 leaves'—which this has."

Among the earliest works in the Sixteenth Century may be mentioned the following:—

TARTARETUS—EXPOSITIO IN SUMMULAS.—EXPOSITIO SUPER TERTU LOGICES ARISTOTELIS—CLARISSIMA SINGULARISQUE TOTIUS PHILOSOPHIE NEC NON METAPHISICE ARISTOTELIS. MAGISTRI PETRI TARTARETI EXPOSITIO. 4to. *Venetiis*, 1504.

The three Expositions are bound together in one volume in solid oak boards covered with white "tooled" vellum or calf and fastened with leather and metal clasps. There is a note on the inside cover calling attention to the varieties in spelling of the author's name in these treatises—one being Tartereti, another Tartareti, and a third Tartarete. The book is printed in black letter.

ALKINDUS AND GAPHAR.—DE PLUVIIS IMBRIBUS ET VĒTIS: AC AERIS MUTATIŌE. 4to. *Venetiis*, 1507. Black letter.

The spelling of the second author's name in this work is, according to the booksellers' catalogues, subject to great variety. In one it appears as Japhar, in another as Gaphar, and in a third (a French list), as Saphar while in the same French catalogue Alkindus appears as Alchindus. The

present volume is in excellent preservation and a fine example of black letter printing.

Notes on Some of the Books.

Many of the books contain notes by Mr. Symons, indicating that the copies are extremely scarce, or that he had to pay a high price for them. A great number of the works are very interesting and valuable. Reference may be made to a few of them as follows :—

LEONARD DIGGES.—A PROGNOSTICATION EVERLASTING OF RIGHT GOOD EFFECT, FRUITFULLY AUGMENTED BY THE AUTHOR, CONTAINING PLAINE, BRIEFE, PLEASANT, CHOSEN RULES TO JUDGE THE WEATHER, ETC. 4to. *London*, 1556. Black letter.

This contains a curious illustration indicating the influences of the constellations upon various parts of the human body.

A STRAUNGE AND TERRIBLE WUNDER WROUGHT VERY LATE IN THE PARISH CHURCH OF BONGAY (printed in 1577, and reprinted in 1820).

On Sunday, August 4, 1577, while divine service was being held between 9 and 10 a.m., a violent thunderstorm occurred at Bungay, in Suffolk, the lightning striking the church and killing several of the worshippers. The account is so weird and graphic that it seems desirable to give the following extract verbatim :—

There were assembled at the same season, to hear divine service and common prayer, according to order, in the parish church of the said towne of Bongay, the people thereabouts inhabiting, who were witnesses of the straungenes, the rarenesse, and soddenesse of the storm, consisting of raine violently falling, fearful flashes of lightning, and terrible cracks of thūder, which came with such unwonted force and power, that to the perceiving of the people, at the time and in the place aboue named, assembled, the Church did as it were quake and stagger, which struck into the harts of those that were present, such a sore and sodain feare, that they were in a manner robbed of their right wits.

Immediately hereupō, there appeared in a most horrible similitude and likenesse to the congregation then and there present, a dog as they might discerne it, of a black colour, at the sight whereof, togither with the fearful flashes of fire which then were seene, moved such admiration in the mindes of the assemblie, that they thought doomes day was already come.

This black dog, or the divel in such a likenesse (God hee knoweth al who worketh all) running all along down the body of the church with great swiftnesse, and incredible haste, among the people, in a visible fourm and shape, passed between two persons, as they were kneeling uppon their knees, and occupied in prayer as it seemed, wrung the necks of them bothe at one instant clene backward, in somuch that even at a momēt where they kneeled, they strāgely dyed.

This is a wōderful example of God's wrath, no dout to terrifie us, that we might feare him for his iustice, or pulling back our footsteps from the pathes of sinne, to love him for his mercy.

To our matter again. There was at ye same time another wonder wrought: for the same black dog, stil continuing and remaining in one and the self same shape, passing by an other man of the congregation in the church, gave him such a gripe on the back, that therwith all he was presently drawen togither with a string. The man, albeit hee was in so straunge a taking, dyed not, but

as it is thought is yet alive : whiche thing is mervelous in the eyes of men, and offereth muche matter of amasing the minde.

Moreouer, and beside this, the Clark of the said Church beeing occupied in cleansing of the gutter of the church, with a violent clap of thunder was smitten downe, and beside his fall had no further harme : unto whom being all amased this straunge shape, whereof we have before spoken, appeared, howbeit he escaped without daunger : which might peradventure seem to sound against trueth, and to be a thing incredible.

L. FROMONDUS.—METEOROLOGICORUM LIBRI SEX. 4to. *Antverpiæ*, 1627.

The cutting from the bookseller's catalogue states "most rare old copy, £2."

FRANCISCI DE VERULAMIO.—HISTORIA NATURALIS ET EXPERIMENTALIS DE VENTIS, ETC. 12mo. *Batavorum*, 1638.

This work, by Lord Francis Bacon, contains four distinct treatises, and is embellished with a quaintly engraved title-page representing the four winds. In the bookseller's catalogue this is stated to be "excessively rare, £3."

In a later edition, published in 1648, the illustration on the title-page is slightly enlarged, but reversed. The price of this copy is mentioned as 42s.

R. P. D. BENEDICTUS MAZZOTTA LICYENSIS.—DE TRIPLICI PHILOSOPHIA, NATURALI, ASTROLOGICA, ET MINERALI. 4to. *Bononiæ*, 1653.

This contains an illustration of a curious wind-vane, which seems to be the precursor of the present Dines' Pressure-Tube Anemometer. A reproduction of the plate on a reduced scale is shown in Fig. 5.

Mr. R. H. Scott has favoured me with a translation of the description of this wind-vane, which is given below.

In order that you may know whence your wind comes see on what line the flag falls, and the wind blows from the opposite quarter. Therefore if the flag gives North the wind is South. In order to see this more perfectly you set up a column, on the extreme top of which you engrave the names of the winds, and place on the top of the capital of the column an iron plate on which you stand an Angel or a boy of brass provided with a bandirola, or a pipe with a flag. Inside the pipe there is a tube like a fife which will produce a sound at the mouth, and in the other hand the figure has a wand. When the wind blows the wand shows the point whence it comes, and the wind gives a note through the boy's mouth. I found this plan was due to P. Valentius Pinus.

FIG. 5.

AN HISTORY OF THE WONDERFUL THINGS OF NATURE. WRITTEN BY JOHANNES JONSTONUS, AND NOW RENDERED INTO ENGLISH BY A PERSON OF QUALITY. 4to. *London*, 1657.

Mr. Symons was of opinion that the translator of this work was John Rowland.

Under the heading of "Dew," the author states: "Plutarch saith that fat women were wont to gather dew with cloaths or soft skins which they used, to make them lean."!

THE BOOK OF KNOWLEDGE. 8vo. *London*, 1660.

Nine editions of this work have been taken from Mr. Symons' Library. In the edition published in 1697, he has inserted the note—"Very scarce: have not seen another perfect copy."

SAGGI DI NATURALI ESPERIENZE, FATTE NELL' ACCADEMIA DEL CIMENTO. Large 4to. *Firenze*, 1666.

Mr. Symons' note to this runs: "I do not understand the date of this book being 1666 while the preface is dated July 14, 1667. This is certainly the first edition, as I can trace no copy in any library earlier than 1667, and very few of that. The English translation in 4to, by R. Waller, Secretary of the Royal Society, was published in 1684. Many interesting details respecting the work of the Accademia are given in the 3rd edition of the *Catalogue of the Special Loan Collection of Scientific Apparatus*, 1877, catalogued by Roy. Soc. under 'Transactions, Florence,' but often under 'Magalotti, L.,' who was Secretary.

"There is another 1666 in Ronalds' Library. See also that catalogue, p. 314, where, quoting Libri. Cat., this ed. is said to be rare, and printed for presents. I think perhaps printed and submitted in proof to the Vicars General. See last page but one."

"REGE SINCERA."—OBSERVATIONS BOTH HISTORICAL AND MORAL UPON THE BURNING OF LONDON, SEPTEMBER 1666. With an Account of the Losses. And a most remarkable Parallel between London and Mosco both as to the Plague and Fire. Also an Essay touching the Easterly Winde. Written by way of Narrative, for satisfaction of the present and future Ages. 4to. *London*, 1667.

There is a written note to the effect that this work is not mentioned in the Bodleian Catalogue, 1843, where is only the reprint in the *Harleian Miscellany*.

The author's account of the East Wind is so interesting that it seems desirable to give the following extract:—

. . . In cometh now the East-wind to play his part in this Tragedy. That unfortunate wind, of which it is commonly said, that it is neither good for man nor beast, did blow with such a wonderful fierceness all the time of the conflagration, that it did not only quicken the fire, as Bellows do the Furnaces, but also getting into the streets, and among the houses, when it found any let or hindrance that did recoil it back, it blew equally both to the right and to the left, and caused the fire to burn on all sides, which hath persuaded many that this fire was miraculous; I myself remember, that going into some streets at the time, and having the wind impetuously in my face, I was in hope that at my return I should have it in my back, but it was all one, for the reason aforesaid. It would be here too tedious to speak of the nature of winds, and to shew many reasons why this wind is so dry in England, as to burn the flowers and leafs of the trees, more than the hottest Sun can do, one which I think satisfactory will serve for all. It is therefore to be observed, that winds do not only participate of the nature of the places where they are begot, but also of that of the Countries thorough which they pass: Now all the Southern, Western,

and Northern Winds must pass through the great Ocean to come into England, in which passage there mixes with them abundance of vapours which cause their moisture, except the North-wind, wherein the moisture is condensed by the cold; but the East-wind to come to us must pass over the greatest Continent of the world, France, Germany, Hungary, Greece, Persia, etc., even to China; so that in perusing such a tract of Land, it not only droppeth down by the way his moist Effluviums, the earth as it were sucking them for its irroration, but also carrieth along all the hot and dry exhalations that perpetually arise out of the earth, which is the cause of his dry and burning quality. I had formerly a little Garden, where I did bestow as much pains and cares as I could, to bring up some young Fruit trees that were in't, having the advantage of a very good mould, but being seated Eastward and closed narrowly by a Brick wall on either side; this wind that raigneth constantly here in England in the moneths of March, April, and beginning of May, did in their budding so burn the leaves and the flowers that the hottest Sun could not do the like, so that I was fain to give it over, having been two or three years before I could understand that mystery, and the nature of that wind in this country, for there is some other countreys where this wind is salubrious and fruitful enough.

JOHN CLEARIDGE (OR CLARIDGE).—THE SHEPHERD'S LEGACY: OR JOHN CLEARIDGE, HIS FORTY YEARS' EXPERIENCE OF THE WEATHER. 8vo. *London*, 1670.

This is the first edition of the work popularly known as "The Shepherd of Banbury's Rules," and the pages have been remounted throughout. There are five subsequent editions of the same work.

A TRUE AND PERFECT NARRATIVE OF THE GREAT AND DREADFUL DAMAGES SUSTEYNED IN SEVERAL PARTS OF ENGLAND BY THE LATE EXTRAORDINARY SNOWS. 4to. *London*, 1674.

This is an interesting account of the heavy snowstorms which occurred during the first week in March 1674.

"Whereby," (as the author says) "above twenty families of poor people, men, women, and children, were distressed, and some destroyed at Langsdale in the Bishoprick of Durham: the snow from the hills covering the tops of their houses that they could not get out, but were afterwards found dead, some of them having pieces of raw beef in their mouths: all their goods being before burnt to keep them warm. As also of a family in Somersetshire, neer Bath, so beset with the snow that they were forced to live three days on nothing but grains; and at last being relieved with victuals, eat so ravenously that the poor woman and five childred immediately dyed. And several persons and great quantities of cattle and sheep lost in Northumberland, Darbyshire, Glocestershire, Shropshire, Lincolnshire, Isle of Ely and other places. Faithfully extracted from letters lately sent from Persons of good credit and quality in all those parts."

This pamphlet concludes with the following quaint verse:—

A feather'd Rain came in Abundance down,
And with dry Inundations did us Drown.

JOHN SMITH.—A COMPLEAT DISCOURSE OF THE NATURE, USE, AND RIGHT MANAGING OF THAT WONDERFUL INSTRUMENT THE BAROSCOPE OR QUICK-SILVER WEATHER GLASS. 8vo. *London*, 1688.

This is the earliest treatise on the manufacture and use of the Mercurial Barometer. In the preface the author says—

Note, that the Honorable Rob. Boyle, Esq., as Dr. Beale tells us, in Phil. Trans. N. 9, p. 153, was the first that ever discovered this Useful Instrument to the English Nation, and therefore does deserve from us all due Acknowledgements for those Benefits which we either have or may hereafter receive by it.

WILLIAM COCK.—METEOROLOGIÆ: OR THE TRUE WAY OF FORESEEING AND JUDGING THE INCLINATION OF THE AIR, AND ALTERATION OF THE WEATHER IN SEVERAL REGIONS. 12mo. *London*, 1703.

Mr. Symons' note is "extremely scarce. I never heard of another copy, and had to pay £1 at Sotheby's for this in July 1894."

AN EXACT RELATION OF THE LATE DREADFUL TEMPEST: Or a Faithful Account of the Most Remarkable Disasters which hapned on that occasion. The Places where, and Persons Names who suffer'd by the same, in City and Countrey: the Number of Ships, Men, and Guns, that were lost, the miraculous Escapes of several Persons from the Dangers of that *calamity* both by Sea and Land. Faithfully collected by an Ingenious Hand, to preserve the Memory of so Terrible a Judgment. 8vo. *London*, 1704.

This is a pamphlet of 24 pages (but bound up with blank leaves, for padding), for which Mr. Symons paid 10s.

It contains an account of "the Great Storm" which occurred on November 26, 1703. [*See* A. GIFFORD, p. 252].

DANIEL DEFOE.—THE STORM: A Collection of the most remarkable Casualties and Disasters, which happen'd in the late dreadful Tempest, both by Sea and Land, on Friday, the Twenty-sixth of November, Seventeen Hundred and Three. Second Edition. 8vo. *London*, 1704.

This is a very full account of the same Storm as that described in the preceding work. [The Society has a copy of the first edition of Defoe's book in the Library.]

JOHN GADBURY.—NAUTICUM ASTROLOGICUM: OR THE ASTROLOGICAL SEAMAN. 8vo. *London*, 1710.

This includes "a Diary of the Weather, Carefully Observed for xxi. Years Compleat, etc., beginning at November the 11th Anno 1668, and ending the 31st of December Anno 1689. Design'd for the Service of Philosophers, Physicians, Astrologers, and all other Faithful Observers of the Various Wonders that are to be found in God's Creation."

This appears to be one of the earliest daily records of the weather kept in London.

R. BUDGEN.—THE PASSAGE OF THE HURRICANE FROM THE SEA-SIDE AT BEXHILL IN SUSSEX TO NEWINGDEN-LEVEL, THE TWENTIETH DAY OF MAY, 1729, BETWEEN NINE AND TEN IN THE EVENING. 8vo. *London*, 1730.

This is one of the earliest discussions on Tornadoes, and is illustrated by a map showing the path and width of the tornado in question. The Author says:—

. . . The distance from the Sea-side to Newingden-Level is about twelve Miles, which it passed over in twenty minutes; and if we take seventy rods for

the mean diameter of the vertiginous motion, the duration of the offensive wind could not exceed twenty seconds; which, if it be considered, how little for the most part the duration of a minute is understood by the persons from whom we are obliged to collect this account, and the unspeakable Horror and Surprize they were in while their houses were shook and torn in pieces over their heads; perhaps few people in such circumstances could guess twenty seconds, much less than half, if not a whole minute. According to this computation, the direct velocity of the Storm is forty-two feet in a second, to which, adding forty-three feet for the increase by the vertiginous or spiral motion, makes eighty-five feet; which is the space run through in every second of time near the outward verge of the gyration and the velocity by which all obstacles received the impulse of the wind.

The way of the tempest, was nearly from South by West to North by East in a direct line, for all variations appeared visibly to be owing and guided by the situation of the surface of the Earth, always inclining and deflected more or less to the East or West, in pursuit of the lower ground.

A. GIFFORD.—A SERMON IN COMMEMORATION OF THE GREAT STORM, COMMONLY CALLED THE HIGH WIND, IN THE YEAR 1703. PREACHED AT THE CHAPEL IN LITTLE WILD STREET, LONDON, NOVEMBER 27, 1733, WITH AN ACCOUNT OF THE DAMAGE DONE BY IT. 8vo. *London*, 1733.

The following extracts give an account of the institution of the sermon, and also particulars of the damage caused by the storm.

The occasion of my insisting on these Words this Day, is in answer to the Request of the surviving Trustee of the late Mr. *William Taylor*, deceas'd; a useful and honourable Member of the Society that meets here, who was so affected with the Great Storm, commonly call'd the High Wind, on this Day thirty Years ago, that he desired it might be annually held in remembrance.

It is agreed upon all Hands, from the Relations given of it by the Writers of that Time, and especially from the Queen's Proclamation, that came out for a Fast on the account of it, that it was the most terrible Desolation of the kind that ever was known in the Memory of Man, or recorded in any History; not only for the Greatness of its Fury, but Continuance, vast Extent, and Damage done by it.

The Wind had been very tempestuous for several Days before; but on *Friday* Evening, *November* 26, in the Year 1703 it sensibly increased, and blew an inexpressibly prodigious Hurricane, till Six or Seven the next Morning, when it began to abate, and, in a few Days (after several considerable Flurries) quite ceased.

According to the most exact Accounts of this horrible Tempest, there were few Houses and Gardens, Orchards or Fields, that did not feel its fatal Power. One who took a great deal of Pains to collect the Damages done by it, by a moderate computation, reckon'd up near three hundred thousand Trees, and some of them of great Bulk, that were either torn up by the Roots, or broken to Pieces, but finding it would be endless to enumerate all, gave over the attempt.

Nine hundred Dwelling-Houses were entirely overthrown by this terrible Blast, by which most of the Inhabitants were much hurt, and many of them miserably perish'd in the Ruins.

Above an hundred Churches, though strongly built, were quite stripped of the Lead that cover'd them, most of which was roll'd up like a Scroll, and carried to an incredible Distance; besides many more that had the Battlements and Steeples wholly destroy'd, and otherwise damaged by it.

Upwards of four hundred Windmills were broke all to Pieces.

And as to Barns and Stables, and other Out-houses, they were beyond numbering.

The Stacks of Hay, and all sorts of Grain, were almost everywhere either wholly blown away, or greatly shatter'd. Several were entirely removed from one Place to another.

In this Great Metropolis the Damage was universal; few, if any of its public or private Buildings escaping its Fury.

But in *Bristol* it was still worse; for, besides the Hurt done immediately by the Wind, it raised such a Tide as did an hundred thousand Pounds Damage to the Merchandize, and caused the *Severn* to overflow its Banks, and drown the adjacent Country for many Miles round, whereby above fifteen thousand Sheep were drowned, and near an hundred of their miserable Owners; several whole Families, with their Habitations and Cattle, being swept away all together. The Loss, in this single Article, was computed at more than two hundred thousand Pounds.

Above twelve hundred Ships, Boats, and Barges, were entirely lost by it, or so shatter'd, as to be rendered useless. It was reckon'd that near nine hundred of them belonged only to the River *Thames*.

But the worst of all is still behind; I mean the Multitudes of Souls that were hereby hurried off the Stage of Life into an unalterable Eternity, many of whom, it is to be feared, were altogether unprepared for so sudden and awful a Change.

Between eight and nine thousand were known to have lost their Lives, either by Sea or Land, including those that were shipwreck'd on the *English* and *Dutch* Shores, some of whom were very valuable and useful.

Among these, I cannot forbear mentioning the great Winstanley, who perish'd with several others, in the *Edistone* Lighthouse near *Plymouth*, of which he was the ingenious Contriver and Architect. And the learned, pious Bishop *Kidder*, whose *Works* will praise him in the Gates, as long as there is an Infidel to question, or scoff at the Mission and Authority of the Son of God, who was, with his Lady, alas! hereby brought to the fatal Period of his useful Life and Labours, thro' the fall of Part of his own Palace.[1]

This is a small Sketch of the Damages done in our own Island; but the whole is unknown. However, from several Accounts put together, one supposes perhaps not without Reason, that it far exceeded that of the Fire of London, which was computed at no less than four Millions Sterling.

BENJAMIN MARTIN.—THERMOMETRUM MAGNUM: OR GRAND STANDARD THERMOMETER. 8vo. *London.* 1772.

This thermometer was intended to express "all degrees of heat and cold, from that with which mercury boils, to that which congeals it into solid metal." The author illustrates this with a large engraving on which he has adjusted "the celebrated scales of Sir Isaac Newton, Fahrenheit, De L'Isle, and Reaumur, for comparing observations made in every part of the Globe, and in all degrees of temperature in the air and any other bodies."

E. EDWARDS.—A SHORT ACCOUNT OF THE HURRICANE THAT HAPPENED AT ROEHAMPTON LANE AND PLACES ADJACENT ON THE FIFTEENTH OF OCTOBER 1780. ILLUSTRATED BY FOUR OUTLINES WASHED AND TEINTED.

This tract, which consists of eight pages only, has been mounted on large

[1] At Wells, Somerset.—W. M.

folio paper and bound up with both plain and coloured illustrations, and with an engraved portrait. There are altogether thirty-nine leaves in the volume, twenty-four of which are blank, having been included simply for the purpose of making it sufficiently thick for binding. A cutting is attached from the bookseller's catalogue, stating that the volume is very scarce and that the price was £6 : 6s.

H. ROOKE.—A METEOROLOGICAL REGISTER KEPT AT MANSFIELD WOODHOUSE IN NOTTINGHAMSHIRE. 8vo. *Nottingham.* 1785–1805.

Mr. Symons has inserted a note: "Extremely scarce. I never saw or heard of another complete copy."

W. BENT.—A METEOROLOGICAL JOURNAL KEPT IN PATERNOSTER ROW, LONDON. 8vo. 1786–1792.

Mr. Symons' note is "Excessively scarce. I never heard of another copy."

THOMAS CREASER.—THE EXTRAORDINARY CASE OF JOSEPH LOCKIER, WHO WAS STRUCK BY LIGHTNING AND EXISTED THREE WEEKS IN A WOOD NEAR BATH ON WATER ONLY! ILLUSTRATED BY ANALOGOUS INSTANCES. PUBLISHED FOR HIS BENEFIT BY THOMAS CREASER, MEMBER OF THE ROYAL COLLEGE OF SURGEONS, LONDON, AND SURGEON TO THE BATH CITY DISPENSARY. 8vo. *Bath.*

It appears that Joseph Lockier was struck down by lightning in a wood during a thunderstorm on August 19, 1806, and was not found until September 8. During that time he had no food, and was only able to collect a little of the rain which fell during a second thunderstorm on August 29. This pamphlet contains his sworn deposition before a magistrate, and also a declaration signed by the physicians and surgeons of the Bath City Dispensary who attended him.

J. H. BARKER.—MEDICAL METEOROLOGY. Reprinted from the Association Medical Journal, August 26, 1853. 4to. *Bedford.*

At the end of this article there is the following interesting and curious note:—

The British Meteorological Society is under the presidency of Samuel Charles Whitbread, Esq., who, at great expense, has erected an excellent Astronomical and Meteorological Observatory in the garden of his country residence at Cardington, Bedfordshire. It may be remembered that this spot was the scene of the meteorological researches of the philanthropist John Howard. The construction of philosophical instruments has been wonderfully improved since the time of Howard! His biographer tells us "At the bottom of his garden at Cardington he had placed a thermometer; and as soon as the frosty weather had set in, he used to leave his warm bed at 2 o'clock every morning, walk in the bitter morning air to his thermometer, examine it by his lamp, and write down its register,—which done to his satisfaction, he would coolly betake himself to bed again." See Hepworth Dixon's *Life of Howard.*

G. J. SYMONS.—BAROMETRICAL DEPRESSION DECEMBER 23-27, 1859. 4to.

Mr. Symons was a frequent correspondent of *The Times* newspaper, writing upon meteorological phenomena of exceptional interest. This

paper, which was printed for circulation among observers, was the outcome of a letter to the *The Times*, and is probably the first printed paper by Mr. Symons. It seems therefore desirable to reproduce the article *in extenso*.

The Table on p. 257 is very characteristic of Mr. Symons, as before he had a barograph he would, during the time of any great depression, "sit up" (to use his own expression) with his barometer and take frequent readings throughout the night. He once supplied me with a copy of barometrical readings which he had taken every 15 minutes from 11.15 p.m. to 7 a.m. (See *Quarterly Journal*, Vol. I. pp. 201-2).

The pressure at this station having in the early morning of December 26 been reduced to a very low point, I inserted a brief note in *The Times*, calling attention to the fact, and intimating that I should be happy to exchange readings with observers. [These readings are given at the end of this article.—W. M.].

The replies to this note were so numerous, and in some cases so complete, that I felt it my duty to compare and discuss them to the best of my ability.

I believe the accompanying Observations and Curves will render the principal features of the depression tolerably evident, especially if the relative position of the Stations be fully realised. Conscious that there are many others far better qualified for this investigation than myself, I will merely add that I shall be most happy to supply with a duplicate of the Observations (some hundreds) any one who will undertake to analyse them more fully.

The scales, etc. of the curves are marked upon them; they are simply graphic representations of the readings, with one exception, viz. in the large tracings, the Camden Town Observations are entered three hours *earlier* than they were actually made. This has been done in order that the angles of depression and elevation may be compared more readily than if the effect of easterly position had not been eliminated.

The column headed "Amount of Depression" is the difference between the Minimum reading and that at 9 A.M. on the 23rd, when the Pressure would appear to have been nearly identical throughout the country. I have adopted this mode in order to get rid of any errors attaching to the Barometer; the difficulty arising from the instrument not being closely watched (whereby the *true* minimum is lost) does not seem so easily obviated.

In conclusion, I have only to thank my friends for their ready contribution of Observations, and to express an earnest wish for suggestions of improvement in, and friendly criticism upon, the mode of treatment.

G. J. SYMONS.

CAMDEN TOWN, *February* 1860.

Barometric Pressure at Sea Level.
December 1859.

Station and Observer.	9.0 a.m. 23rd.	24th.	25th.	26th.	27th.	Minimum Observed. Time.	Pressure.	Amount of Depression
	Inches	Inches	Inches	Inches	Inches		Inches	Inches
GUERNSEY. Dr. Hoskins, F.R.S., &c.	29·540	29·277	29·107	28·837	29·448	26th, 9 a.m.	28·837	0·703
TRURO. Dr. Barham	·509	·079	28·883	·919	·279	25th, 9 p.m.	·436	1·073
LITTLE BRIDY. H. S. Eaton, Esq., B.A., &c.	·561	·194	29·080	·777	·388	26th, 3 a.m.	·528	1·033
EXETER. W. H. Ellis, Esq., M.B.M.S.	·560	·158	·020*	·850	·353	25th, 11 p.m.	·530	1·030
CLIFTON. W. C. Burder, Esq., M.B.M.S.	·575	·127	·048	·787	·343	26th, 3 a.m.	·588	0·987
UCKFIELD. C. L. Prince, Esq., F.R.A.S., &c.	·604	·294	·186	·664	·470	,, 9 a.m.	·664	0·940
CAMDEN TOWN. G. J. Symons, Esq., M.B.M.S., &c.	·567	·198	·081	·674	·379	,, 6 a.m.	·629	0·938
LEICESTER. James Payne, Esq.	·577	·098	·045	·796	·290	,, 9 a.m.	·796	0·781
†NOTTINGHAM— E. J. Lowe, Esq., F.R.A.S., &c.	·591	·083	·069	·844	·297	,, 3 a.m.	·746	0·845
HOLKHAM. S. Shellabear, Esq., M.B.M.S.	·562	·102	·040	·783	·280	,, 9 a.m.	·783	0·779
MANCHESTER. G. V. Vernon, Esq., F.R.A.S., &c.	·557*	·007*	·019*	·882*	·245*	25th, 11 p.m.	·848	0·709
WAKEFIELD. W. R. Milner, Esq., M.B.M.S., &c.	·608	29·049	29·062	·897	·232	26th, 3 a.m.	·847	0·761
NORTH SHIELDS. Robert Spence, Esq.	·477	28·935	28·985	28·875	·105	,, 9 a.m.	28·875	0·602
BRAEMAR. Messrs. Pearce and Cameron	29·562	29·022	29·027	29·117	29·167	25th, 9 p.m.	29·000	0·562

* Computed from readings made within one hour of the above time (9 a.m.).

Southampton (James Sharp, Esq.), the Observations being made at 3 p.m., could not be inserted above; the minimum observed was 28.540, at 3.30 a.m. on the 26th.

† *Tottenham* (W. D. Howard, Esq.); the minimum observed was 28.651.

Observations with other than Standard Instruments or for which the whole of the corrections are not known.
December 1859.

Station and Observer.	9.0 a.m. 23rd.	24th.	25th.	26th.	27th.	Minimum Observed. Time.	Pressure.	Amount of Depression
	Inches	Inches	Inches	Inches	Inches		Inches	Inches
BARNSTAPLE. J. R. Chanter, Esq.	29·55	29·10	28·98	29·00	29·33	25th, 9 a.m.	28·98	0·57
†ALDERSHOT. J. Arnold, A.H.C., &c.	·54	·24	29·13	28·58	·40	26th, 9 a.m.	·58	0·96
LAMPETER. Rev. Prof. J. Matthews, M.A., &c.	·567	·092	28·983	·963	·290	25th, 4 p.m.	·827	0·74
OUNDLE. George Ellick, Esq.	29·55	29·13	29·07	28·79	29·29	26th, 9 a.m.	28·79	0·76

Red Hill, Reigate (Richard Witherby, Esq.): the minimum did not occur till towards noon on the 26th.

† Not communicated, but obtained from published returns.

BAROMETRICAL DEPRESSION.

December 23-27, 1859.

The following Observations of the Pressure at Sea-Level are computed from the readings of two Standard Barometers at Camden Town, London—125 feet above Sea-Level.

Date.	Time.	Pressure. Inches.	Date.	Time.	Pressure. Inches.
Dec. 23	9.0 a.m.	29·567	Dec. 26	3.0 a.m.	28·655
,,	9.0 p.m.	29·463	,,	4.0 ,,	28·642
24	9.0 a.m.	29·198	,,	5.0 ,,	28·632
,,	9.0 p.m.	29·088	,,	5.30 ,,	28·633
25	0.40 a.m.	29·060	,,	6.0 ,,	28·629*
,,	9.0 ,,	29·081	,,	6.30 ,,	28·634
,,	2.49 p.m.	29·024	,,	7.0 ,,	28·639
,,	7.0 ,,	28·861	,,	7.30 ,,	28·647
,,	9.0 ,,	28·776	,,	8.0 ,,	28·657
,,	10.0 ,,	28·748	,,	9.0 ,,	28·674
,,	10.30 ,,	28·732	,,	Noon	28·744
,,	11.0 ,,	28·726	,,	9.0 p.m.	29·167
26	Midnight	28·701	27	Midnight	29·234
,,	1.0 a.m.	28·680	,,	9.0 a.m.	29·379
,,	2.0 ,,	28·668	,,	9.0 p.m.	29·458
,,	2.30 ,,	28·663	,,	11.0 ,,	29·443

* This, the minimum reading, was reached at 5.50 by one instrument, and 6.10 by the other; the former fell .001 in. lower than the above quoted value.

Maximum for the year	1858 = 30·699,	on January	17th at	9.0 a.m.
,, January,	1859 = 30·830,	on January	9th at	11.40 p.m.
,, November,	1859 = 30·763,	on November	10th at	9.0 p.m.
,, December,	1859 = 30·773,	on December	10th at	11.5 a.m.
Minimum for the year	1858 = 29·012,	on November	27th at	5.0 p.m.
,, October	1859 = 29·068,	on October	26th at	0.35 a.m.
,, November,	1859 = 28·790,	on November	1st at	1.15 p.m.

G. J. SYMONS.

Queen's Road, Camden Town, N.W.,
December 28th.

HENRY DOXAT.—THE LUNAR ALMANAC. 8vo. *London*, 1862.

The price of this almanac for the year 1862 was sixpence, but for the years 1864 to 1868 the price was one guinea for 16 pages! In 1869 the price had fallen to one shilling.

ELIJAH WALTON.—CLOUDS: THEIR FORMS AND COMBINATIONS. 3rd Edition. 4to. *London*, 1873.

This volume contains forty-two plates of photographic reproductions of carefully and beautifully prepared drawings illustrating the forms and combinations of clouds.

Weather-Maps and Diagrams.

In the collection there are numerous weather-maps, charts, and diagrams. I would call attention to three which seem to me to be of peculiar interest:—

Exhibition 1851.—Atmospheric Maps: showing the direction of the wind, the barometric pressure, and the state of the weather at various places in Great Britain from observations collected by The Electric Telegraph Company at the Great Exhibition, August 11 to October 11, 1851. 4to. *London*, 1851.

Mr. Symons reproduced what he called "The First Daily Weather-Map," viz. that for August 8, 1851, which was the first of this series, in the *Meteorological Magazine* for September 1896.

Weather-Map of the British Isles.

There are two of these maps, viz. those for August 5 and September 3, 1861. These were published by "The Daily Weather-Map Company, Limited."

The Prospectus of this Company, whose capital was £4000 in 400 shares of £10 each, is so interesting and optimistic that I cannot refrain from reproducing it herewith:—

This Company is formed for the purpose of raising capital to carry on the publication of the *Daily Weather-Map*. All the preliminary expenses are already provided for. The patent is sealed; the instruments have been prepared, corrected by the Greenwich standard, and distributed to the various stations; the Map is engraved, the Symbols completed, and every arrangement made for completing the publication. Only so much additional capital is required as would suffice to defray current expenses until the returns from Sale and Advertisements can be realised.

These returns are likely to be speedy and ample. The novelty of its design will secure for the *Weather-Map* immediate celebrity. It will, besides, contain intelligence specially interesting to very large and numerous classes of the community—among others (1) the Sailor; (2) the Merchant and Shipowner; (3) the Agriculturist; (4) all who travel by land or by water; (5) the Scientific public, who present a large, influential, and rapidly increasing body; (6) every one who observes, studies, or talks about the Weather—the subject which proverbially forms the first subject of conversation between Englishmen.

Being sold at so moderate a price, and addressing so large a section of the community, the sale of the *Weather-Map* will in all probability be very extensive; while it will present, in proportion to the number of its readers, a first-rate medium for advertisements. The revenue from both sources cannot fail to be very considerable. The expenses, on the other hand, are comparatively moderate. Including the cost of Telegraphic Despatches, of printing (exclusive of double numbers), of Literary and Scientific Contributions, and of Office Expenses, the outlay will amount to between £8 and £9 per diem, or about £52 per week. If printed on paper of the best quality, the net proceeds of sale, after deducting the cost of paper, machining, and allowance to the trade, will leave a profit of fully £3 : 10 : 0 per thousand. A circulation of 3000 copies would therefore pay all expenses, leaving the receipts from advertisements clear gain. If 5000 circulation were attained—and the number is not large for a paper sold at so moderate a price—the annual profits from sale alone would exceed £2000 per annum, or more than 50 per cent on the investment. But even a much more moderate circulation would command an extensive display of high-class advertisements furnishing an ample source of profit to the Shareholders.

In order to limit individual responsibility, the proprietorship in the publication has been constituted into a partnership under the Limited Liability

Act. No shareholder can consequently incur any risk beyond the amount of the shares which he may think proper to take. Half the nominal amount of such shares will be required upon allotment, the residue being called up if wanted, and as wanted, to meet the current expenses of the publication.

Further particulars may be obtained from, and applications for shares addressed to, "The Manager of the Weather-Map Company (Limited)," 110 Strand, W.C.

Subscription :—4s. per month, 13s. per quarter, £2 : 12s. per annum.

DALTON'S METEOROLOGIST. Folio. *Manchester*, 1854.

This is an elaborately illuminated diagram arranged by Bennet Woodcroft, exhibiting "at one view the mean monthly state of the rain-gauge, the barometer, and the thermometer at Manchester, from data kept for upwards of twenty years and tables formed by the late Dr. John Dalton." There is also shown on the diagram the mean monthly and annual temperature in the Crimea, and a note is added to the effect that "the profit derived from the sale of this print will be appropriated to the Patriotic Fund."

Manuscripts.

Mr. Symons had in his collection two MSS. on vellum of the works of Albertus Magnus: the first of these a beautifully illuminated MS. on vellum, the initial letter (historiated with a portrait of Albertus Magnus) with border and arms of the Medici family in gold and colours, and with painted capitals. This was purchased in 1881 at Sotheby's for the sum of £4 : 15s.

Mr. Symons has inserted the following note—"Albertus Magnus, or Albrecht Count of Bollstädt, was born in 1205 at Lauingen in Bavaria. He was a Dominican teacher in the schools of his order at Hildesheim, Ratisbon, Cologne, and Paris, and subsequently (from 1254 to 1259) Provincial of the Order in Germany. He was ordained Bishop of Ratisbon in 1260, but two years afterwards he retired to the monastery at Cologne, where he died Nov. 15, 1280.

"The complete series of his works was published at Leyden in 1654 in 21 folio volumes, but parts, if not the whole, were printed as early as 1488.

"This MS. on vellum is a Commentary on Aristotle's Meteorology, and forms part of the IV. vol. of Albertus' works. It bears no date, but is probably of the 15th century."

The second MS. is entitled "Compendium Alberti Magni de Negotio Naturali." This work, which is also illuminated, but not so extensively as the preceding, forms a small 4to volume, for which Mr. Symons apparently paid £3 : 16s.

The Symons Bibliography.

Although not included in the Bequest, I must make some reference to the Bibliography compiled by Mr. Symons, and which has been purchased by the Society from his executors for the sum of £100.

This consists of the titles of all books, pamphlets, papers, articles, etc., bearing on meteorology of which Mr. Symons had any knowledge.

These titles, together with particulars as to size, date, place of publica-

tion, etc., are entered on cards either in MS. or cuttings from booksellers' catalogues and other sources. The cards are all placed in boxes in a strictly alphabetical manner under the name of the author, and each author's cards are arranged according to date. There are about 60,000 titles which are contained in 147 boxes 4½ inches high, 8 inches wide, and 11½ inches deep.

This is a most valuable compilation, and a rich storehouse of information on meteorological literature. Mr. Symons greatly prized this bibliography, to the compilation of which he had devoted so many years of his life. I trust that the Society will be able to carry on this valuable work, and so keep up to date the record of all known publications bearing on the science of meteorology.

Conclusion.

It is truly marvellous how Mr. Symons got together such an extensive and valuable collection of books and pamphlets. He was ever on the look-out for meteorological works, and used to receive several second-hand booksellers' catalogues daily. These he would carefully go through, and if he found any work mentioned which he did not already possess, he at once took steps to secure it. I remember him telling me some years ago how one Saturday evening he received a catalogue from a bookseller in the Strand, and found a book mentioned which he was very anxious to secure. He knew that others were also on the look-out for the same work, so he got up early on Monday morning and went down to the Strand and waited until the shop door was opened. He at once asked for the book and paid for it before the bookseller had time to open his letters —which contained several orders for the same book!

I will conclude by quoting the following words with reference to Mr. Symons from Dr. C. Theodore Williams' Jubilee Address:—

"When we review his life and work we cannot but come to the conclusion that he has not lived in vain; that while himself actively urging on the progress of meteorological science, he organised his large body of efficient workers to pursue his labours after him, and he bequeathes to us—most precious legacy of all—his own bright example."

THE PERIODICITY OF CYCLONIC WINDS.

By RUPERT T. SMITH, F.R.Met.Soc.

[Read May 15, 1901.]

An attempt is made in this paper to show the stormy periods of the year by a principle of wind differentiation somewhat novel, and for this purpose the daily wind observations, both for direction and force, have been arranged into three categories—"Cyclonic," "Anticyclonic," and "Periodic." With the first of these only it is proposed to deal on the present occasion.

The volume of cyclonic wind over one station during a fair term of 26 years gives a very decided preponderance of wind force about 2 weeks before the vernal equinox and 3 weeks after the autumnal equinox.

The observations extend from 1874-99, and were made in one locality, bounded by Birmingham, Wolverhampton, and Stourbridge, and by one observer, at 5 different stations varying in height from 378 to 879 feet above sea-level.

The direction of the wind was taken at 9 a.m. daily over the 26 years. The force of the wind was taken the same for the first 11 years, but from 1885 to 1899 the average force of the 24 hours was estimated daily.

The scale of wind force (converted into pressures) used is as under:—

Land Scale.	Velocity. Miles per Hour.	Pressure. Lbs. per Sq. Ft.
1	10	·5
2	25	5·0
3	40	10·0
4	55	21·0
5	70	26·0
6	85	32·0

This is practically similar to that known as "FitzRoy 1863," which is as under:—

Sea Scale.	Character of Wind.	Land Scale.	Velocity. Miles per Hour.	Pressure. Lbs. on Sq. Ft.
1– 3	Light	0–1	10	½
3– 5	Moderate	1–2	25	3⅛
5– 7	Fresh	2–3	40	8
7– 8	Stormy	3–4	55	15⅛
8–10	Heavy	4–5	70	24½
10–12	Violent	5–6	85	36⅛

The figures of this land scale 0–6 are half those of the Beaufort scale, and afford the additional advantage that when squared they give approximately the pressure in pounds per square foot.

There were 45 occasions during the 26 years when force 5 was reached, and one occasion when force 6 was reached.

The direction of the wind, and also the force of the wind for every day, has been classified under 3 subheads—"Cyclonic," "Anticyclonic," and "Periodic."

The direction and force of "cyclonic" winds are entered as such when the barometer reduced to sea-level shows a lower pressure than 29·8 ins., and when the incurving isobars show that some portion of the circular storm is definitely over the station.

The direction and force of winds that occur during the incidence of an anticyclone, where the barometric pressure is at or over 30·0 ins., and where the synoptic chart confirms the superposition, are entered under the subhead of "Anticyclonic" wind.

Again, wind, both direction and force, is booked as "Periodic" wind when the barometer is at average pressure for the time of year, when the synoptic isobars are straight, and when the appearance of the weather renders it doubtful of classification.

Calm days have been eliminated. The barometer readings and oscillations referred to are reduced for temperature and elevation, and the wind entries have of late years been checked weekly by the returns of the Meteorological Office.

With the subheads of "Anticyclonic" and "Periodic" winds I am not now directly concerned. The "Cyclonic" wind direction and pressure is only used for this present purpose.

Having thus subdivided the wind into 3 categories, I now proceed to deal with the wind under the heading of "Cyclonic."

Here the winds of all the stormy (cyclonic) weather of the period are

TABLE I.—Diurnal Frequency of Cyclonic Wind Days, 1874-99.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6	11	8	6	8	5	6	5	8	9	7	3
2	7	11	8	7	7	6	9	9	10	6	10	4
3	8	10	7	8	6	6	6	11	9	9	10	7
4	10	6	6	8	5	6	4	11	7	11	11	6
5	9	7	8	10	4	8	5	11	9	9	11	6
6	8	4	9	12	5	6	8	8	7	9	9	11
7	8	7	8	10	4	9	9	7	7	9	12	10
8	10	9	10	6	4	9	7	8	5	7	11	8
9	9	9	12	7	6	7	7	9	6	11	12	9
10	7	11	10	5	4	6	10	9	9	10	11	8
11	8	10	8	4	8	4	7	8	8	8	10	8
12	6	8	6	7	4	4	5	10	9	8	11	11
13	6	7	5	7	3	3	7	11	8	7	10	11
14	8	9	5	7	5	3	9	9	7	11	13	8
15	9	7	6	5	6	4	5	8	7	12	11	8
16	8	9	5	5	9	3	7	8	5	11	12	9
17	9	8	6	5	10	3	4	7	5	11	8	6
18	11	8	7	4	10	4	5	6	7	8	4	8
19	7	9	6	7	11	4	4	7	9	7	7	8
20	7	10	11	5	11	5	6	9	9	7	5	8
21	8	10	6	9	7	5	6	10	10	9	6	7
22	9	8	5	7	7	7	11	11	12	11	6	8
23	7	8	6	9	4	6	9	9	8	9	5	4
24	6	11	10	9	5	4	8	9	8	9	8	8
25	10	8	11	9	5	5	10	10	7	9	14	4
26	8	11	11	5	6	6	9	12	8	11	14	9
27	9	6	9	4	7	8	6	12	11	12	11	10
28	7	5	10	6	6	9	6	11	12	6	10	12
29	9	...	12	4	6	5	4	11	11	7	8	12
30	8	...	9	3	5	5	6	8	11	6	7	11
31	5	...	10	...	2	...	4	7	...	5	...	9
Total . .	247	237	250	200	190	165	209	281	249	274	284	251
Mean . .	8·0	8·5	8·1	6·7	6·1	5·5	6·7	9·1	8·3	8·8	9·2	8·1
Barometer Oscillation	in. 1·142	in. ·870	in. ·972	in. ·889	in. ·755	in. ·677	in. ·615	in. ·703	in. ·812	in. 1·088	in. 1·055	in. 1·149

entered, with direction, frequency (Table I.), and pressure summations (Table II.), the total number of cyclonic days, and the total number of lbs. pressure in the number of those cyclonic days.

It is thus seen that the cyclonic wind pressure given in the diurnal columns of the month are total pressures; the means at foot of both tables are the mean numbers of cyclonic days in the months in Table I., and the mean pressures per cyclonic day in the months in Table II. This last being the column totals divided by the column totals of Table I., and showing the daily means of cyclonic pressure in each month independent of frequency, and by these figures the relative daily storminess of the separate months can be seen.

TABLE II.—DIURNAL CYCLONIC WIND PRESSURES (LBS. PER SQ. FT.) 1874-99.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	36·1	73·1	97·5	51·6	97·2	58·7	37·6	42·0	78·3	29·4	57·4	15·5
2	55·8	104·3	108·7	60·3	66·7	60·0	77·5	79·9	94·1	23·2	84·9	29·1
3	65·3	91·7	60·1	71·7	79·1	26·7	58·2	101·5	63·0	51·6	67·9	73·3
4	86·0	34·0	62·0	56·4	53·1	41·1	41·0	35·6	42·0	36·1	73·1	64·4
5	77·5	43·3	88·8	71·9	25·9	100·1	32·0	88·0	49·4	34·6	68·4	62·5
6	84·4	28·6	121·6	92·0	51·2	36·1	69·6	54·1	25·1	47·2	64·4	11·9
7	76·4	62·4	83·1	82·5	32·1	52·6	86·2	33·9	52·2	45·9	92·9	78·3
8	74·4	98·9	121·7	67·5	22·5	40·5	41·0	45·8	49·0	71·6	104·5	102·6
9	43·1	87·8	117·0	66·2	47·9	47·1	57·0	49·9	47·2	90·6	82·6	82·4
10	35·5	94·1	71·6	41·1	6·5	54·6	87·2	51·9	42·1	68·4	110·1	42·8
11	88·6	112·5	70·0	48·8	49·0	33·5	57·1	31·6	64·2	84·9	82·8	50·2
12	29·7	84·7	57·2	73·1	40·8	22·5	35·4	52·5	65·2	63·6	106·3	94·6
13	46·7	67·2	47·5	66·1	41·1	6·1	73·8	68·1	41·7	91·1	90·3	89·6
14	41·2	39·7	47·4	68·5	46·1	34·8	75·8	49·6	41·7	134·6	92·1	73·3
15	36·2	41·8	58·5	31·5	107·6	55·1	27·5	85·1	64·6	135·0	69·9	90·0
16	68·9	101·0	85·7	46·6	120·7	20·9	58·8	27·6	51·2	98·4	95·3	72·1
17	80·8	44·2	44·1	62·7	99·2	18·0	2·8	33·5	25·4	61·6	68·5	27·4
18	97·9	32·5	58·2	36·5	69·4	18·0	22·9	41·5	35·0	51·7	34·4	60·9
19	66·9	81·2	57·1	68·4	73·7	32·1	38·9	42·8	37·3	26·3	75·0	69·5
20	39·8	121·6	83·5	42·4	115·0	41·7	29·2	59·3	43·6	38·9	46·4	73·7
21	73·9	67·9	39·1	55·9	42·5	55·4	51·7	45·6	57·2	54·3	83·0	30·9
22	70·3	49·3	46·1	59·0	48·2	69·9	74·4	56·9	109·0	64·7	63·0	29·3
23	81·2	88·9	53·1	84·4	16·2	46·6	58·4	52·9	23·6	67·0	73·2	37·3
24	48·1	88·9	86·9	109·4	26·9	25·5	67·1	49·7	28·4	49·2	83·8	74·2
25	74·6	73·1	112·5	80·8	16·6	15·1	68·6	25·4	61·0	40·1	92·4	6·7
26	90·4	140·6	128·2	35·5	30·6	18·1	48·5	90·4	64·0	59·0	105·2	49·2
27	82·5	54·5	93·7	11·6	33·9	49·9	48·2	68·1	82·8	78·9	96·1	70·5
28	74·1	51·0	108·9	37·2	48·5	40·0	79·7	63·4	56·3	59·0	80·9	96·4
29	109·2	...	93·0	20·8	51·2	29·4	57·1	109·7	59·4	57·2	35·7	68·5
30	80·3	...	44·1	24·6	22·7	36·1	56·5	34·3	106·5	40·2	49·3	82·7
31	39·8	...	60·4	...	1·1	...	40·5	36·4	...	25·3	...	94·9
Total	2055·6	2058·8	2407·3	1725·0	1583·2	1186·2	1656·6	1707·0	1660·5	1879·6	2329·8	2004·7
Cyclonic Days.	247	237	250	200	190	165	209	281	249	274	284	251
Mean Pressure per Day.	8·3	8·6	9·7	8·6	8·0	7·2	8·0	6·1	6·7	6·8	8·2	8·0

To amplify this last point, Table III. gives the relative storminess of every cyclonic day in detail. It is at once seen from this what irregular fluctuations of relative pressure occur through the months.

Taking the tables together, it is seen from Table I. that the greatest

consecutive number of days of cyclonic wind occur from November 2 to 16, but Tables II. and III. show pressures of that period below the average. The next stormy period of days of cyclonic wind is from March 24 to 31, but the greatest consecutive number of days of superior pressure are shown in Table III. as occurring from February 26 to March 8, although March 25 to 28 are also high.

Table I. shows the large number of cyclonic days in the latter half of August; by Table II. it will be seen that the corresponding pressures were light.

TABLE III.—AVERAGE DAILY CYCLONIC WIND PRESSURES, 1874-99.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	6·0	6·6	12·2	8·6	12·2	11·7	6·3	8·4	9·8	3·3	8·2	5·2
2	8·0	9·5	13·6	8·6	9·5	10·0	8·6	8·9	9·4	3·9	8·5	7·3
3	8·2	9·2	8·6	9·0	13·2	4·5	9·7	9·2	7·0	5·7	6·8	10·5
4	8·6	5·7	10·3	7·1	10·6	6·9	10·3	3·2	6·0	3·3	6·6	10·7
5	8·6	6·2	11·1	7·2	6·5	12·5	6·4	8·0	5·5	3·8	·6·2	10·4
6	10·6	7·2	13·5	7·7	10·2	6·0	8·7	6·8	3·6	5·2	7·2	10·2
7	9·6	8·9	10·4	8·3	8·0	5·8	9·6	4·8	7·5	5·1	7·7	7·8
8	7·4	11·0	12·2	11·3	5·6	4·5	5·9	5·7	9·8	10·2	9·5	12·6
9	4·8	9·8	9·8	9·5	8·0	6·7	8·1	5·5	7·9	8·2	6·9	9·2
10	5·1	8·6	7·2	8·2	1·6	9·1	8·7	5·7	4·7	6·8	10·0	5·4
11	11·1	11·3	8·8	12·2	6·1	8·4	8·2	4·0	8·0	10·6	8·3	6·3
12	5·0	10·6	9·5	10·4	10·2	5·6	7·1	5·3	7·2	8·0	9·7	8·6
13	7·8	9·6	9·5	9·4	13·7	2·0	10·5	6·2	5·2	13·0	9·0	8·1
14	5·2	4·4	9·5	9·8	9·2	11·6	8·4	5·5	6·0	12·2	7·1	9·2
15	4·0	6·0	9·8	6·3	17·9	13·8	5·5	10·6	9·2	11·3	6·4	11·3
16	8·6	11·2	17·1	9·3	13·4	7·0	8·4	3·5	10·2	8·9	7·9	8·0
17	9·0	5·5	7·4	12·5	9·9	6·0	0·7	4·8	5·1	5·6	8·6	4·6
18	8·9	4·1	8·3	9·1	6·9	4·5	4·6	6·9	5·0	6·5	8·6	7·6
19	9·6	9·0	9·5	9·8	6·7	8·0	9·7	6·1	4·1	3·8	10·7	8·7
20	5·7	12·2	7·6	8·5	10·5	8·3	4·9	6·6	4·8	5·6	9·3	9·2
21	9·2	6·8	6·5	6·2	6·1	11·1	8·6	4·6	5·7	6·0	13·8	4·4
22	7·8	6·2	9·2	8·4	6·9	10·0	6·8	5·2	9·1	5·9	10·5	3·7
23	11·6	11·1	8·9	9·4	4·1	7·8	6·1	5·9	3·0	7·4	14·6	9·3
24	8·0	8·1	8·7	12·2	5·4	6·4	8·4	5·5	3·6	5·5	10·5	9·3
25	7·5	9·1	10·2	9·0	3·3	3·0	6·9	2·5	8·7	4·5	6·6	1·7
26	11·3	12·8	11·7	7·1	5·1	3·0	5·4	7·5	8·0	5·4	7·5	5·5
27	9·2	9·1	10·4	2·9	4·8	6·2	8·0	5·7	7·5	6·6	8·7	7·1
28	10·6	10·2	10·9	6·2	8·1	4·4	13·3	5·8	4·7	9·8	8·1	8·0
29	12·1	...	7·8	5·2	8·5	5·9	14·3	10·0	5·4	8·2	4·5	5·7
30	10·0	...	4·9	8·2	4·5	7·2	9·4	4·3	9·7	6·7	7·0	7·5
31	8·0	...	6·0	...	0·6	...	10·1	5·2	...	5·1	...	10·5
Mean	8·3	8·6	9·7	8·6	8·0	7·2	8·0	6·1	6·7	6·8	8·2	8·0

Again, the heavy winds of the middle of May do not quite synchronise as regards pressure and frequency; May 15 having 6 cyclonic days only on Table I., but a total pressure of 107·6 lbs. (Table II.), giving a daily mean of 17·9 lbs. (see Table III.), the highest daily rate of cyclonic wind of the year. May 16, again, shows (Table I.) 9 cyclonic days and a total pressure (Table II.) of 120·7 lbs., giving a daily rate of 13·4 (see Table III.).

Very little regularity in the intervals of storminess is apparent, but if Table III. be smoothed it is not without indications of 13 average intervals of 28 days each throughout the year.

The term of years is obviously insufficiently long to give the necessary smoothness for this to be actually observed.

The equinoxes themselves do not show as very stormy periods,—at least the spring one does not,—but all the tables show that the frequency and force of cyclonic wind occurs some 2 weeks before the spring equinox and some 3 weeks after the autumn equinox, notwithstanding the winter steepness of isobars and the greater oscillation of the barometer in the winter months; December, January, October, November, and March being the order of the months of most barometric oscillation in cyclonic weather.

February 26 is the day of maximum wind pressure over the period, followed by October 14 and 15. The middle of May from the 15th to the 20th is again a very stormy period, as shown in Tables I., II., and III.

TABLE IV.—Weekly Totals of Cyclonic Wind Pressures—26 Years.

Week.	N.	E.	S.	W.	Resultants.		Week.	N.	E.	S.	W.	Resultants.	
					Total.	Direction.						Total.	Direction.
	lbs.	lbs.	lbs.	lbs.	lbs.			lbs.	lbs.	lbs.	lbs.	lbs.	
1	24·7	94·9	217·7	144·2	481·5	S 18 W	27	17·2	10·8	163·1	214·4	405·5	W 38 S
2	67·6	46·3	138·2	107·1	359·2	S 42 W	28	22·2	22·1	152·5	217·0	413·8	W 36 S
3	40·2	107·3	179·3	137·5	464·4	S 16 W	29	18·4	19·8	94·2	146·3	278·7	W 34 S
4	58·7	24·0	206·3	232·2	521·2	W 36 S	30	39·4	15·5	184·1	185·0	424·0	W 41 S
5	86·1	34·9	195·2	216·2	532·4	W 34 S	31	57·3	29·4	185·1	172·2	444·0	W 43 S
6	76·2	49·6	219·3	182·5	527·6	S 43 W	32	8·4	17·4	163·4	130·5	319·7	S 38 W
7	35·1	46·7	167·7	161·6	411·1	S 42 W	33	39·2	32·9	105·6	170·5	348·2	W 29 S
8	66·6	96·5	169·1	238·7	570·9	W 38 S	34	32·3	18·4	129·0	200·5	380·2	W 31 S
9	71·8	47·4	205·4	249·8	574·4	W 36 S	35	12·8	16·2	206·1	249·2	484·3	W 41 S
10	131·9	33·8	142·6	365·5	673·8	W 3 S	36	32·2	10·2	109·5	176·0	327·9	W 28 S
11	65·5	37·7	87·4	208·0	398·6	W 1 S	37	39·5	32·7	126·1	172·4	370·7	W 34 S
12	130·5	107·0	28·9	211·9	478·3	W 22 N Equinox	38	68·6	25·7	111·0	125·8	331·1	W 27 S Equinox
13	170·0	90·4	102·1	217·4	579·9	W 31 N	39	59·9	37·8	128·9	231·8	458·4	W 24 S
14	96·2	227·1	94·9	84·1	502·3	E	40	51·6	22·3	77·1	117·0	268·0	W 19 S
15	78·8	113·9	89·4	112·2	394·3	S 12 E	41	49·7	31·3	289·1	234·7	604·8	S 41 W
16	32·1	146·0	101·6	92·8	372·5	S 39 E	42	76·0	84·9	118·0	187·3	466·2	W 26 S
17	75·0	76·6	136·9	91·2	379·7	S 17 W	43	83·6	92·0	89·6	152·7	417·9	W 8 S
18	39·5	66·5	149·6	142·2	397·8	S 33 W	44	36·8	40·7	175·0	155·5	408·0	S 41 W
19	58·6	55·9	79·7	45·7	239·9	S 29 E	45	85·6	169·7	151·5	196·9	603·7	S 26 W
20	104·8	65·4	187·5	274·0	631·7	W 25 S	46	52·3	68·7	214·2	221·6	556·8	S 44 W
21	21·1	22·8	76·3	94·7	214·9	W 40 S	47	95·9	82·3	99·0	239·6	516·8	W 2 S
22	1·3	51·0	136·8	79·8	268·9	S 16 W	48	49·1	62·9	147·8	152·0	411·8	S 43 W
23	49·9	109·0	86·7	126·5	372·1	S 29 W	49	93·1	58·4	190·2	233·7	575·4	W 33 S
24	4·2	16·8	100·4	69·5	190·9	S 42 W	50	77·9	27·8	187·5	219·4	512·6	W 33 S
25	38·2	4·9	65·3	180·8	289·2	W 12 S	51	29·0	19·6	127·6	152·8	329·0	W 38 S
26	9·8	14·3	126·9	75·2	226·2	S 31 W	52	24·3	29·6	261·1	228·1	543·1	S 43 W

The storm periods are unevenly divided over the year, as has been shown before. The storminess of July and August is more apparent than real, the high ratio being due more to the monsoonal atmospheric depressions than to wind storms. June is the month of least storm. November shows as the stormiest month on Table I., but as the 5th month in strength of wind on Table II. November also is the month of least range of wind pressure.

Although anticyclones are said to accompany cyclones, they do not appear to do so; the number of anticyclonic days from March 24 to 31 being the fewest in this 26-year period.

Finally, Table IV. shows the cyclonic wind aggregate pressures of the years in weeks. It is seen that the second week before the spring equinox

holds the strongest wind of the year, and that with the one exception of the twentieth week (middle of May) the second week after the autumn equinox is the next strongest for cyclonic winds—the days will be found to be 13 days before the vernal and 22 days after the autumnal equinox respectively.

In spite of the chaotic condition of wind force registration, the relative pressures of this paper have been taken the same throughout, and are all comparable, if their scale is not absolutely correct in itself.

Some years ago, in 1884, and again in 1887, inquiry was made as to these winds, on both occasions by periods of 15 days, and without finding the equinoctial periods very stormy.

The foregoing is another aspect of the same inquiry, and may perhaps be considered as sufficient to at least keep the verdict open as to whether the equinoctial periods are or are not, as Lucretius says, "the war time of the year."

DISCUSSION.

Mr. R. H. Curtis said that the author had certainly treated the subject of Wind Periodicity in a novel manner, but he was afraid the new method was in no way an improvement on others which were older, and, indeed, that it only tended to increase the "chaotic condition" of the subject referred to by the author in one of the closing paragraphs of his paper. Apparently Mr. Smith had estimated the direction and force of the wind at 9 a.m. each day, and had assumed that that one observation was sufficient to indicate the wind conditions for 24 hours; and although, during the latter 15 years of the period dealt with, he had, as regards *force* only, made a general estimate for the whole day, yet he (the speaker) feared the change was insufficient to improve to any great degree the initial value of the data used in the discussion. For the purpose of this estimation of force the author had chosen an obsolete wind scale which had gone out of general use many years ago, and which possessed no single advantage, whilst it did possess serious disadvantages, compared with the Beaufort scale which was now almost universally employed by meteorologists. Having thus chosen his scale, the author had proceeded to change the estimated forces into equivalent pressures, and here again he had left the beaten paths and used a scale of pressure equivalents of his own devising. Having quoted the pressure equivalents given by Admiral FitzRoy for the velocity equivalents of the "land scale," and also a dictum of Mr. Harding's, that the numbers of that scale, if squared, give approximately the equivalent pressures in pounds per square foot, Mr. Smith had ignored both, without saying why, and had used instead a scale of pressure which, as far as can be seen, rests upon no experimental or observational basis whatever. No fact in connection with wind pressure is more certain than that it varies as the square of the velocity; but in the author's scale, for equal velocity increments of 15 miles, from 10 miles to 85 miles per hour, we have increments of pressure of 4·5, 5, 11, 5, and 6 pounds respectively, with the result that force 4 of this scale, which is probably the most frequently recurring force, is credited with a pressure equivalent relatively much in excess of that given to any other number of the scale. This fact had probably a great deal to do with the obviously too high average pressures given in the Tables II. and III. of the paper.

Another novelty in the author's procedure was the way in which he had divided his winds into cyclonic, anticyclonic, and "*periodic*" types. Apparently the fact of the barometer at his station reading below 29·8 ins., or above 30·0

ins., was the main factor which determined into which class a given day should be thrown, for we are told that only "of late years" have these wind entries "been checked weekly by the returns of the Meteorological Office." But he (the speaker) dissented altogether from the use the author made of the term "*periodic*," which, in meteorology, has a very well understood and definite meaning, not at all agreeing with what Mr. Smith apparently wished to convey. Probably all our winds are cyclonic or anticyclonic; but if the general distribution of pressure at a given time is such as to make it difficult to say which of the two classes of system is dominant, which is apparently what the term "periodic" is intended to convey, the word "indefinite" would much better express the fact. It was also purely wrong to regard all cyclonic weather as *stormy* weather, and to use the two terms as being interchangeable, as Mr. Smith appears to have done. The results of the discussion are not better than the author's method of proceeding would lead one to expect. It is difficult to see what useful purpose Table II. can serve, since it contains only the summation of the individual observations of pressure, which convey nothing to the mind until they have been divided by the numbers in Table I., and this has been done in Table III. From Table I. we learn that August is, with one exception, the month of most frequent storm, and from Table III. that the average strength of a storm is as great in May and July as in December. We are also told that the average wind pressure in a storm occurring on May 15 amounts to 17·9 lbs. per square foot—a wind pressure which is in reality equal to a velocity of nearly 80 miles per hour! and each of these conclusions is contrary to experience. What the author means exactly when he speaks of "13 average intervals of storminess of 28 days each throughout the year," is not at all clear; neither is it quite obvious how he has proceeded in constructing his Table IV., especially as regards his direction resultants.

No doubt Mr. Smith had expended a great deal of time and trouble in the preparation of his paper, and it was greatly to be regretted that, owing to the want of a more carefully considered and legitimate plan, his labour had been so largely spent in vain; but to a very large extent the paper was distinctly misleading, and it ought to be made clear that it did not represent the views of the Fellows generally upon the subject of wind periodicity, either as regards the methods followed or the results obtained.

Mr. W. Ellis said that a paper of this kind involved a great deal of work, and it was with reluctance that he offered any adverse criticism, but he must point out that the observations of wind force having been estimated on a scale of 0–6, the corresponding pressures in lbs. on the square foot, adopted by the author of the paper, do not in his opinion form a satisfactory scale, which is to be regretted, as such defect is a fundamental one causing the numbers in the tables and the discussion of the results to be, in his opinion, alike vitiated thereby.

Mr. R. Inwards thought that the observations would have shown up much better if presented in a diagrammatic form. If the author's conclusions were correct, he did not think they would have escaped the attention of so many other observers who had studied the matter of periodicity in weather especially in connection with the moon.

Mr. F. J. Brodie said that the results given in Table IV. were so remarkable that one could not help thinking that the author's method of working must have been in some way defective. January was well known to be the stormiest month, but in the table the total wind pressure given for each of the first 4 weeks was much lower than at many other times in the year. He (Mr. Brodie) had for some time past been engaged on an enquiry as to the prevalence of gales in this country, and was therefore able to confirm the statement as to the tendency for stormy weather in the tenth week of the year. With regard, however, to the other periods of maximum wind pressure shown in Table

IV., there appeared to be very grave doubt, and particularly so in the case of the second maximum. That the twentieth week in the year (corresponding with the third week in May) should be classed as the second stormiest period seemed quite inexplicable, and was altogether opposed not only to experience, but so far as he was aware to any reliable data in existence.

THE PRESIDENT (Mr. W. H. DINES) said it was not clear whether the pressures given in the tables referred to the average pressure, or the maximum that might be expected in a gust. In the former case they were far too great, and even in the latter he thought they were still from 10 to 20 per cent too great. An average pressure of 30 lbs. per sq. ft. maintained for an hour or so would not leave a tree or building standing, and it was certain no such thing occurred in nature, unless it might be for a minute or so during the passage of the violent whirlwinds so well known in America as tornadoes. Of late years a few reliable pressure plates had been erected in England, which were free from the errors incidental to the old form of pressure plate, and on these as yet no pressure exceeding 24 lbs. per sq. ft. had been recorded.

Mr. R. T. SMITH in reply, said that he was hardly prepared for the strength of the criticism. He was scarcely responsible for the peculiarities of the scales. He had chosen two out of more than half a hundred available ones which were given in a recent paper by Mr. R. H. Curtis. He was aware that a pressure of 36 lbs per sq. ft. was very large, but the average for May 16 over the 26 years was 6¾ lbs only, including all classes of wind. Possibly this high reading was the effect of the scale used. For some of the earlier years the direction and force of the wind at 9 a.m. was entered as that for the whole day, but from 1885 several observations daily had been made, and an estimate from these had been registered. The term "periodic" winds was chosen for want of a better name, and he thought any other nomenclature would have been equally open to objection. He did not think it required a very experienced observer to distinguish between cyclonic and anticyclonic conditions; and, as stated in the paper, the observations had been checked week by week with the *Weekly Weather Report*. With reference to the 28-day intervals, he had no intention of smuggling in a lunar period; and as stated, more observations were required to bring this out. Only "cyclonic" winds were noticed in the paper, and the tables showed a great rise of such winds at the several times mentioned. For several successive years heavy storms had been experienced on May 15 and 16, which accounted for the very high pressures on those days. He had been in the Tropics, and he certainly thought that traces of the Monsoon periods could be noticed in the torrential rains and thundery weather of July. Other observers, too, made reference to this. In the last table he thought that the dividing up of the winds under the four points of the compass might be useful, and the equinoctial periods were thus clearly brought out.

THE ECLIPSE CYCLONE, THE DIURNAL CYCLONES, AND THE CYCLONES AND ANTICYCLONES OF TEMPERATE LATITUDES.

BY H. HELM CLAYTON.

[Read June 19, 1901.]

The Eclipse Cyclone.

THE part of the United States between New Orleans and Norfolk, along which occurred the total solar eclipse of May 28, 1900, was visited by several trained observers and experts, who went primarily to see the eclipse phenomena, but took meteorological observations during the eclipse as a contribution to the science of the subject.

These observations were made with sling or aspiration psychrometers and with portable wind-vanes and anemometers which, at Washington, Ga., were self-recording. The observations at Washington, Ga., lat. 33° 44′ N., long. 82° 45′ W., were taken by Mr. A. Lawrence Rotch and Mr. S. P. Fergusson; at Wadesboro, N.C., lat. 34° 59′ N., long. 80° 5′ W., they were taken by myself; at Centerville, Va., lat. 36° 41′ N., long. 76° 11′ W., they were taken by Mr. O. B. Cole; at Virginia Beach, Va., lat. 36° 50′ N., long. 75° 39′ W., they were taken by Mr. G. W. Pickard. Besides these observations I procured complete meteorological records from a number of well-equipped meteorological observatories in North America. These observatories were the Toronto Meteorological Observatory, lat. 43° 39′ N., long. 79° 17′ W., R. F. Stupart, Director; the meteorological station at Cornell University, lat. 42° 27′ N., long. 76° 29′ W., Robert G. Allen, Director; the New York Central Park Meteorological Observatory, lat. 40° 46′ N., long. 73° 58′ W., Dr. Daniel Draper, Director; the Blue Hill Meteorological Observatory, lat. 42° 13′ N., long. 71° 7′ W., A. Lawrence Rotch, Director; and Belen College Observatory, Havana, lat. 23° 8′ N., long. 76° 35′ W., Lorenzo Gangoiti, S.J., Director. Besides these, there were partial records from M'Gill College, Montreal, Providence, R.I., and Bayonne, N.J. These observatories were all within the area of partial eclipse, and the data were furnished by the kindness of the directors.

The observations and the details of their discussion are published in the *Annals of the Astronomical Observatory of Harvard College* (vol. xliii. No. 1, "Observations and Investigations of the Blue Hill Meteorological Observatory," A. Lawrence Rotch, Director).

There are certain conclusions of general interest derived from the results, and these I desire to present for the consideration of the Royal Meteorological Society. But, before giving these, it seems best to review briefly the methods used in the discussion of the observations.

The meteorological changes due to the eclipse were separated from other changes of greater length, such as the diurnal and the cyclonic, by interpolating a uniform change between the beginning and the end of the eclipse and subtracting this from the observations. For example, in Fig. 1 is plotted the observations of temperature at Wadesboro, N.C.

The outside vertical lines, B and E, show the beginning and end of partial eclipse, and the central vertical lines, T, show the time of total eclipse. The dotted straight line connects the observed temperatures noted at the beginning and end of the eclipse, and represents the interpolated uniform change. The observed temperatures are shown by

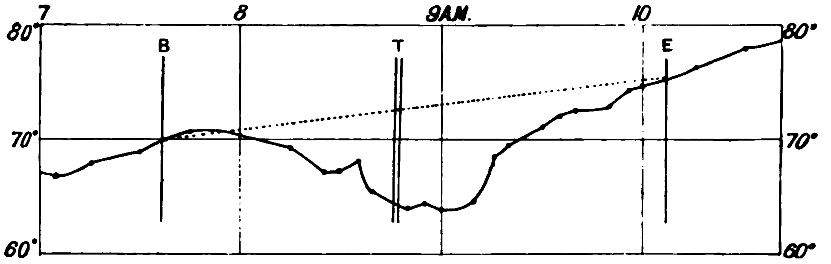


Fig. 1.

the unbroken curved line, and the departures of these from the values represented by the dotted line are assumed to be the depression of temperature arising from the eclipse. The pressure, humidity, and vapour tension were treated in the same manner. These departures for four selected stations are given in Table I. for intervals of 15 minutes, 75th meridian time. There is probably a certain amount of error in this method of separation, but, in the conditions existing at the time of the eclipse of May 28, these residual errors must have been small in comparison with the changes due to the eclipse.

TABLE I.—Departures of Temperature, Relative Humidity, and Vapour Tension produced by the Eclipse.

Washington, Ga.				Wadesboro, N.C.				Toronto, Can.				Havana, Cuba.			
Time, 75th Meridian.	Temperature.	Relative Humidity.	Vapour Tension.	Time, 75th Meridian.	Temperature.	Relative Humidity.	Vapour Tension.	Time, 75th Meridian.	Temperature.	Relative Humidity.	Vapour Tension.	Time, 75th Meridian.	Temperature.	Relative Humidity.	Vapour Tension.
a.m.	°	%	ins.	a.m.	°	%	ins.	a.m.	°	%	ins.	a.m.	°	%	ins.
7.41	+0·2	0	·00	7.45	+0·6	− 1	·00	7.45	...	...	...	7.30	−0·1	0	·00
7.56	+0·1	+ 2	·00	8.00	−0·7	0	−·01	8.00	0·0	0	·00	7.45	−0·5	+2	·00
8.11	0·0	+ 3	+·01	8.15	−2·1	+ 5	·00	8.15	−0·4	+1	·00	8.00	−0·7	+3	·00
8.26	−2·0	+ 5	+·01	8.30	−4·5	+13	+·02	8.30	−1·1	+3	+·01	8.15	−1·1	+4	+·01
8.41	−3·5	...	...	8.45	−7·6	+21	+·05	8.45	−2·8	+7	+·01	8.30	−1·7	+4	+·01
8.56	−4·8	+16	+·03	9.00	−9·0	+29	+·08	9.00	−3·7	+8	+·01	8.45	−1·4	0	+·01
9.11	−4·2	+20	+·07	9.15	−5·0	+14	+·05	9.15	−4·3	+8	+·01	9.00	−0·5	0	·00
9.26	−2·3	+ 8	+·04	9.30	−3·0	+ 5	+·01	9.30	−3·9	+5	·00	9.15	−0·2	0	·00
9.41	−2·1	+ 4	+·02	9.45	−1·8	+ 1	·00	9.45	−2·8	+3	·00	9.30	+0·1	0	·00
9.56	0·0	0	+·00	10.00	−0·5	+ 1	+·01	10.00	−1·1	+1	·00	9.45	0·0	0	·00

Note.—The departures are from a straight line connecting the beginning and ending of the eclipse when the observations are plotted in a curve. The observations at Washington, Ga., were taken every 10 minutes, but for purposes of comparison are reduced to 15-minute intervals by taking the mean of two at alternate intervals; thus the values at 8.26 a.m. are the mean of the values observed at 8.21 a.m. and 8.31 a.m. The thick line through the middle of the table shows the time of maximum eclipse, or totality.

In order to obtain the eclipse wind in velocity and direction, the observations were plotted in the following manner:—In the accompanying diagram, Fig. 2, O, let the connected arrows represent the observed winds in velocity and direction at equal consecutive intervals; then the

broken arrow AB represents the direction of the mean wind, and, when its length is divided by the number of observations, the result gives the velocity of the mean wind. In Fig. 2, P, let AB represent the direction and velocity of the mean wind, and AC the wind observed at any moment during the eclipse, then completing the parallelogram of forces AD will

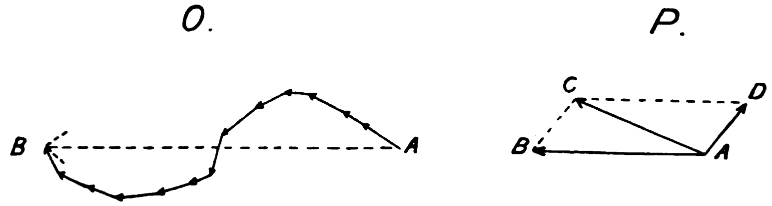


Fig. 2.

represent the eclipse wind in direction and velocity, assuming the deflection of the wind from the mean direction during the eclipse to be due to the eclipse.

As a check on the plotted results and for greater accuracy, the eclipse winds were next computed for certain stations where the observations were sufficiently accurate to warrant it. The mean wind direction was computed by the formula,

$$\operatorname{Tan} \Theta = \frac{\Sigma(v \sin o)}{\Sigma(v \cos o)}$$

in which Θ is the mean wind direction, o is the observed wind direction in degrees of azimuth, and v is the observed wind velocity. In obtaining the sum of the sines and cosines, they are given the proper signs of the quadrants.

The mean velocity was obtained by the formula,

$$V = \sqrt{\left(\frac{\Sigma(v \sin o)}{n}\right)^2 + \left(\frac{\Sigma(v \cos o)}{n}\right)^2}$$

in which V is the mean velocity and n is the number of observations.

In the accompanying diagram (Fig. 3),

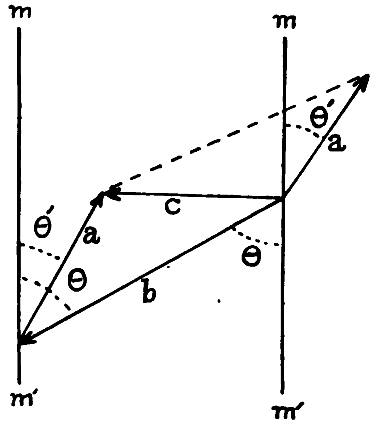


Fig. 3.

Let b = mean (or prevailing) wind velocity.
c = observed wind velocity.
a = eclipse wind velocity.
A, B, and C are angles opposite a, b, and c.
A = angle of observed wind and mean wind.
B = angle of observed wind and eclipse wind.
C = angle of eclipse wind and mean wind.
Θ = direction of the mean wind in degrees.
Θ' = direction of the eclipse wind in degrees.

Then solving the triangle abc,

$$\tan \tfrac{1}{2}(B - C) = \frac{b - c}{b + c} \cos \tfrac{1}{2}A.$$

$$\tfrac{1}{2}(B + C) = 90^\circ - \tfrac{1}{2}A.$$

$$C = \tfrac{1}{2}(B + C) + \tfrac{1}{2}(B - C)$$

$$a = \frac{(b - c) \cos \tfrac{1}{2}A}{\sin \tfrac{1}{2}(B - C)}.$$

$\Theta' = \Theta \pm 180 \mp C$ (plus when o, the observed wind,

is to the right of the mean wind; minus when o is to the left of the mean wind).

The eclipse wind was computed by these formulæ for Washington, Ga., Wadesboro, N.C., and Blue Hill. For the other stations the graphic solution was deemed sufficient, because the error of plotting was much less than errors resulting from lack of sufficient detail in the observations. This insufficiency of detail in the observations arose chiefly from the wind directions being recorded to 8 or 16 points of the compass instead of in degrees. Also the small time-scale used in recording the wind velocity at one or two of the observatories rendered great accuracy in determining the wind velocity impossible. The eclipse winds determined in this manner, when plotted, indicate very clearly an outflow of wind from around the umbra, and an inflow around the borders of the penumbra. The word "umbra" is used to indicate the area of total eclipse, and "penumbra" to indicate the area of partial eclipse. But the plotted results show certain irregularities due to the irregular fluctuations usual to the wind. In order to diminish the effect of these, the observations were smoothed by the formula $\frac{a+2b+c}{4}$. The smoothed values for seven stations are given in Table II. These winds were plotted at their proper places on maps of the United States for 8.15 a.m., 75th meridian time, when the umbra was about to enter the American continent from the Pacific; and

TABLE II.—Eclipse Winds.

Smoothed by formula $\frac{a+2b+c}{4}$.

Time, 75th Meridian.	Washington, Ga.		Wadesboro', N.C.		Blue Hill, Mass.		New York, N.Y		Ithaca, N.Y.		Toronto, Can.		Havana, Cu	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Ve
a.m.	°	miles	°	miles	°	miles	°	miles	°	miles	°	miles	°	mi
7.15	...	...	N 8 W	0·5	...	...	...	...	...	...	...	...	S 55 W	1
7.30	...	...	N 84 E	0·6	...	...	...	...	...	...	...	...	S 77 E	0
7.45	N 73 W	0·5	S 54 E	0·3	N 67 E	2·3	...	...	...	...	...	...	N 34 E	1
8.00	N 65 W	1·3	S 17 W	0·4	N 47 E	2·2	N 6 W	2·6	S 44 W	1·1	...	...	N 4 W	1
8.15	N 67 W	1·0	N 57 W	0·4	N 33 E	2·0	N 9 E	3·1	S 81 W	1·3	W	2·2	N 50 W	0
8.30	N 62 E	0·5	N 40 W	1·0	N 19 E	1·3	N 27 E	3·3	N 79 W	1·3	W	1·2	S 46 W	0
8.45	N 70 E	2·1	N 21 E	0·4	N 53 W	0·8	N 38 E	1·8	N 59 W	1·5	W	0·5	S 1 E	0
9.00	N 70 E	2·4	N 86 E	0·9	S 82 W	1·5	S 35 E	0·4	S 85 W	0·9	N	0·8	N 81 E	1
9.15	N 37 E	0·8	S 46 E	0·8	S 57 W	1·4	S 6 E	1·1	S 7 E	0·6	NE	3·4	N 75 E	3
9.30	N 89 W	0·7	S 37 W	0·8	S 14 W	1·3	S 5 W	1·7	N 69 E	1·1	NE	2·8	N 74 E	4
9.45	...	...	N 79 W	1·6	S 5 E	1·4	S 17 W	2·3	N 44 E	1·5	WNW	2·1	N 79 E	4
10.00	...	...	N 61 W	1·6	S 10 W	1·0	S 28 W	2·8	N 22 E	1·2	W	2·1	N 72 E	3
10.15	...	...	N 45 W	1·1	S 66 W	0·8	S 36 W	3·5	...	...	...	...	...	..
10.30	...	...	...	...	N 64 W	1·3	...	...	...	...	...	...	...	..

Note.—In obtaining these smoothed means only the observed values at 15-minute intervals were used. The thick line through the middle of each series indicates the middle of the eclipse or totality.

also plotted for 9 a.m., when the umbra had passed off the coast of the United States on to the Atlantic Ocean. These maps are shown in Figs. 4 and 5. The position of the umbra is shown on each map by a dark circular area. The depressions of temperature by the eclipse are shown by the numerals on the maps, and isotherms are drawn in dotted lines.

The weather conditions are indicated by symbols, and the direction and velocity of the eclipse wind are indicated by the direction and the length of the arrows.

The number of stations is not large, but the two charts show a reversal of the winds as the umbra moved from one side of the continent to the other, giving evidence of an anticyclonic outflow extending from the central area of the penumbra out to a distance of about 1500 miles. At

FIG. 4.

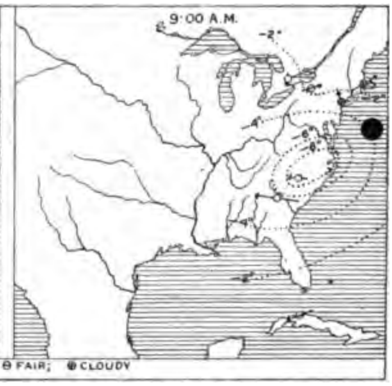


FIG. 5.

the time of Fig. 4 the stations were so far in advance of the centre of the eclipse that no appreciable depression of temperature is shown; but in Fig. 5, which was at the time of greatest depression of temperature at Wadesboro, Washington, and Virginia Beach, there is a central area shown by the isotherms where the depression of temperature exceeds 8°. This area lags behind the umbra about 500 miles. But these charts show only a portion of the eclipse shadow, which extended from near the tropics to the pole, and was about 5000 miles in diameter. Hence the charts do not show the winds in the outer area of the shadow, nor the successive changes which occurred at any given station. The eclipse shadow travelled about 2000 miles an hour, and a synoptic chart can be constructed by placing the observations at each given station on a chart in its proper relation to the centre of the eclipse shadow, allowing for a movement of about 500 miles for each interval of 15 minutes.

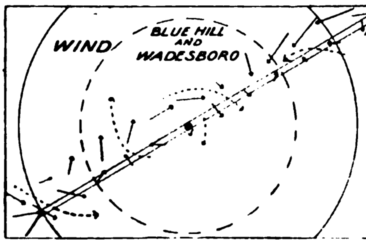


FIG. 6.

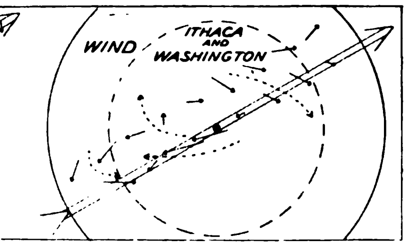


FIG. 7.

In this way Figs. 6 to 9 were constructed. In all of these diagrams the direction and the width of the path of the umbra are indicated by

parallel lines forming long arrows. The central dark area shows the umbra, and the outer circle, or portion of a circle, shows the outer limit of the penumbra. Fig. 6 shows the eclipse winds at Blue Hill and at Wadesboro. The directions are plotted in degrees, and the velocities are shown by the lengths of the arrows. Fig. 7 shows the same thing for Ithaca, N.Y., and Washington, Ga. The air circulation is similar in each case, and this fact indicates that the circulation shown by the resultant winds followed the eclipse shadow, and must have been produced by it. Fig. 8 is a composite, in which the arrows north of the path of the umbra are the mean of Ithaca and Blue Hill, the arrows along the path are the mean of Washington, Ga., and Wadesboro, N.C., and the

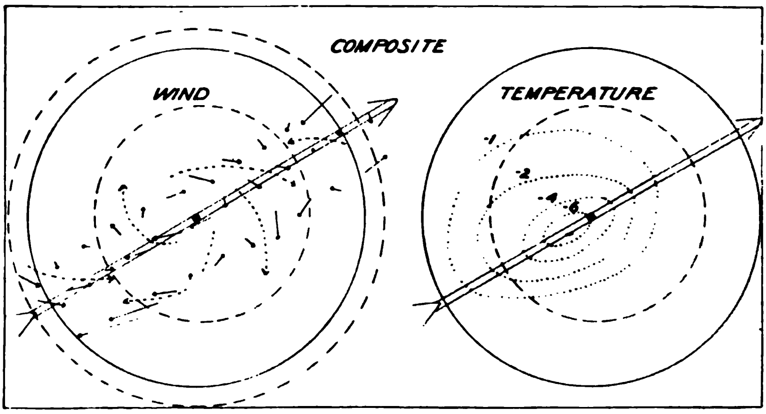


FIG. 8. FIG. 9.

arrows south of the path represent the eclipse winds at Belen College, Havana. The wind directions at this station were recorded to only 16 points of the compass, and hence cannot be given the same weight as the more numerous and more exact observations to the north. Fig. 9 gives the isotherms derived from the mean temperatures in different portions of the eclipse area. The isotherms show an elliptical area with the greatest depression of temperature about 500 miles in the rear of the eclipse cyclone. Furthermore, the isotherms are not symmetrical on each side of the path of the eclipse shadow, probably because of the greater land surface and the greater cooling on the north side of the path. There was less cooling at the stations where dense clouds prevailed, and also less cooling at elevated stations, like Blue Hill, than at other stations equally distant from the eclipse. This appears to indicate that the chief cooling within the eclipse shadow was near the surface of the earth, a fact which might also be inferred from the analogy to the diurnal cooling at night.

The shape and position of the areas of relative and absolute humidity in the eclipse are similar to those of the temperature, except that the departures are *plus* instead of *minus*.

The change of temperature and of humidity in this eclipse is similar to that observed at the individual stations in previous eclipses, but no attempt to chart the data synoptically has previously been tried. The

increase of absolute humidity in the eclipse is somewhat puzzling, but the fact of such an increase during eclipses is amply confirmed by observations in previous eclipses. It is shown by the published observations of Prof. Upton and Mr. Rotch, made in Russia in 1887 and in California in 1889 (*American Meteorological Journal*, vol. iv. p. 362; also *Annals of the Astronomical Observatory of Harvard College*, vol. xxix. p. 7). A marked increase of absolute humidity was also found by Mr. Eliot in the Indian eclipse of 1898. The most plausible explanation of this increase is that, preceding the eclipse, the vapour exuding from the soil is carried away by ascending currents, but as these cease with the oncoming of the eclipse the vapour accumulates near the ground. Possibly also, in some cases, it may be added to by descending currents, as suggested by Mr. Eliot for India.

The changes in atmospheric pressure in eclipses are small, and the conclusions of different observers in regard to the kind of change observed has been so conflicting that some students have doubted the existence of any change. One well-known writer went so far as to say that observers of future eclipses might safely leave their barometers at home (*American Meteorological Journal*, vol. iv. p. 583). In the eclipse of August 19, 1887, Prof. Hesehus found a slight lowering of the pressure (*Nature*, vol. xxxviii. p. 625); while for the same eclipse Schönrock noted only a slight maximum of pressure, which followed the eclipse about 1 hr. and 30 min. (*Repertorium für Meteorologie*, vol. xii.). For the eclipse of January 22, 1898, in India, Mr. Eliot, after eliminating the diurnal period, found an increase of pressure of about ·04 in., which he thought was probably due to the eclipse (*Indian Meteorological Memoirs*, vol. xi. No. 2).

In the eclipse of May 28, 1900, there was an aneroid barometer observed by Mr. Fergusson in the path of totality. There were several mercurial barograph records within the penumbra, and, fortunately, also the record of a delicate air-barograph at Toronto. The air-chamber of this barograph was sunk several feet in the ground to protect it from changes of air temperature, so that it would only record changes in atmospheric pressure. The general plan of the instrument is described by Mr. F. Napier Denison in the *Report of the British Association*, Dover, 1899. The record was kindly furnished by Mr. R. F. Stupart, Director, and is reproduced in Fig. 10 on the same scale as the original, without change in any way, except that a straight dotted line connecting the beginning and ending of the eclipse is drawn through the curve.

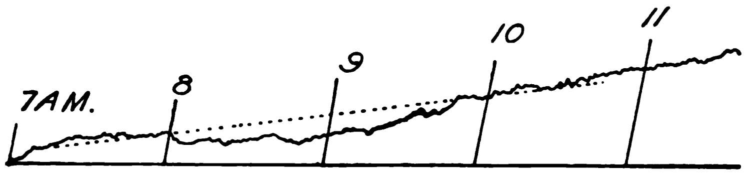


FIG. 10.

The eclipse began at Toronto about 7.47 a.m. and ended about 10.18 a.m. It is seen that the recorded pressure was generally below the dotted line throughout the eclipse, but, immediately preceding and following the beginning and ending of the eclipse, the curve rises above

the dotted line, indicating a ring of high pressure surrounding the penumbra. The change of pressure observed by Mr. Fergusson at Washington, Ga., in the central line of the eclipse is of a similar nature,

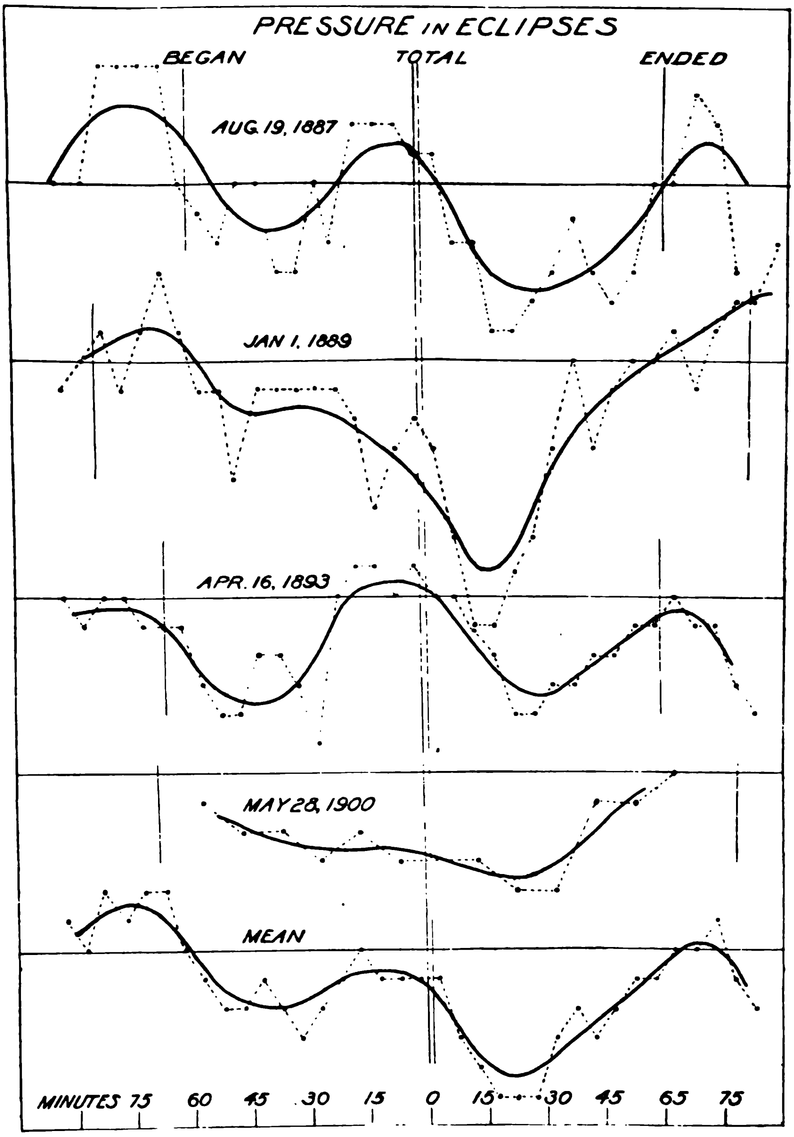


FIG. 11.

except that there was also a noticeable increase of pressure about the time of totality (see Fig. 11).

In order to get the normal changes of pressure due to eclipses, I procured all the accessible observations of pressure during eclipses, and used the following methods to separate the changes due to the eclipse

from changes due to other causes :—(1) where there were observations on other days sufficient to give the normal diurnal period, this was subtracted from the observed pressures on the day of the eclipse; (2) the longer changes due to the movements of cyclones and anticyclones were eliminated by interpolating a uniform change between the beginning and ending of the eclipse, such as is represented by the dotted line in Fig. 10. The results from the observations of Prof. Upton and Mr. Rotch during several eclipses are given in Table III., which shows the changes in pressure during each eclipse and the mean of all, including the observations of Mr.

TABLE III.—Pressure Departures during Eclipses.

Russia. August 19, 1887.		United States. January 1, 1889.		Chile. April 16, 1893.		United States. May 28, 1900.		Mean.
Began 6 hr. 5 min. Total 7 hr. 3 min. Ended 8 hr. 6 min.		Began 12 hr. 24 min. Total 13 hr. 49 min. Ended 15 hr. 8 min.		Began 7 hr. 15 min. Total 8 hr. 21 min. Ended 9 hr. 22 min.		Began 7 hr. 2 min. Total 8 hr. 21 min. Ended 9 hr. 22 min.		
Local Time.	Pressure.	Local Time.	Pressure.	Local Time.	Pressure.	Local Time.	Pressure.	Pressure.
a.m.	ins.	p.m.	ins.	a.m.	ins.	a.m.	ins.	ins.
5·30	...	12·15	·000	6·45	+·002	6·35	...	...
5·33	·000	12·20	–·002	6·50	+·001	6·40	...	·000
5·38	·000	12·25	–·001	6·55	+·002	6·45	...	+·001
5·43	+ ·004	12·30	·000	7·00	+·002	6·50	...	+·002
5·48	+ (·004)	12·35	–·002	7·05	+·001	6·55	...	+·001
5·53	+ ·004	12·40	·000	7·10	+·001	7·00	...	+·002
5·58	+ ·004	12·45	+·002	7·15	+·001	7·05	(·000)	+·002
6·03	·000	12·50	+·002	7·20	–·001	7·10	– ·001	·000
6·08	– ·001	12·55	–·001	7·25	–·003	7·15	– (·001)	–·001
6·13	– ·002	1·00	–·001	7·30	–·003	7·20	– ·002	–·002
6·18	·000	1·05	–·004	7·35	–·002	7·25	– (·002)	–·002
6·23	·000	1·10	–·001	7·40	·000	7·30	– ·002	–·001
6·28	– ·003	1·15	–·001	7·45	·000	7·35	– (·002)	–·002
6·33	– ·003	1·20	–·001	7·50	–·003	7·40	– ·003	–·003
6·38	·000	1·25	·000	7·55	–·005	7·45	– (·003)	–·002
6·43	– ·002	1·30	·000	8·00	+·000	7·50	– ·002	–·001
6·48	+ ·002	1·35	–·001	8·05	+·001	7·55	– (·002)	·000
6·53	+ ·002	1·40	–·005	8·10	+·001	8·00	– ·003	–·001
6·58	+ (·002)	1·45	–·003	8·15	·000	8·05	– (·003)	–·001
7·03	+ (·001)	1·50	–·002	8·20	+·001	8·10	– (·003)	–·001
7·08	+ ·001	1·55	–·003	8·25	·000	8·15	– (·003)	–·001
7·13	– ·002	2·00	–·006	8·30	·000	8·20	– ·003	–·003
7·18	– ·002	2·05	–·009	8·35	–·001	8·25	– (·003)	–·004
7·23	– ·005	2·10	–·009	8·40	–·002	8·30	– ·003	–·005
7·28	– ·005	2·15	–·007	8·45	–·004	8·35	– (·004)	–·005
7·33	– ·004	2·20	–·006	8·50	–·004	8·40	– ·004	–·005
7·38	– ·003	2·25	–·004	8·55	–·003	8·45	– (·004)	–·004
7·43	– ·001	2·30	–·001	9·00	–·003	8·50	– ·004	–·002
7·48	– (·003)	2·35	–·003	9·05	–·002	8·55	– (·003)	–·003
7·53	– ·004	2·40	–·001	9·10	–·002	9·00	– ·001	–·002
7·58	– ·003	2·45	·000	9·15	–·001	9·05	– (·001)	–·001
8·03	·000	2·50	·000	9·20	–·001	9·10	– ·001	–·001
8·08	·000	2·55	+·001	9·25	·000	9·15	– (·001)	·000
8·13	+ ·003	3·00	–·001	9·30	–·001	9·20	– ·001	·000
8·18	+ ·002	3·05	·000	9·35	–·001	9·25	·000	·000
8·23	– ·003	3·10	+·002	9·40	–·003	9·30	·000	–·001
8·28	– ·005	3·15	+·001	9·45	–·004	9·35	...	–·002
8·33	– ·004	3·20	+·003	9·50	...	9·40	...	...

Note.—The horizontal lines in the table indicate the time of beginning and ending of the eclipse and the time of totality. The figures in parentheses are interpolated values.

ısson in 1900. It is seen from these figures that the extreme change the *plus* to the *minus* departures during the eclipse is only a few ısandths of an inch, rarely amounting to as much as ·01 inch. The ıes in Table III. are plotted in Fig. 11, as shown by the dotted curves, ı are smoothed by drawing thick lines through them. In Fig. 11 the ıe of totality in the eclipse is indicated by two parallel vertical lines, d the times of beginning and ending of the eclipse are indicated by ıort vertical lines. The curves show distinctly a maximum pressure bout the time of totality, on each side of which are minima of pressure, ınd outside of the penumbra on each side are maxima of pressure. These minima and maxima are probably parts of a ring of minimum and maximum pressure surrounding the eclipse, and are in perfect accord with the distribution of pressure indicated by the winds in Fig. 8.

The departures for the eclipse in Russia of August 19, 1887, as derived from the mean of 23 stations given by Schönrock in the *Repertorium für Meteorologie* (vol. xii.), and also the mean departures derived from 21 stations in India, treated in the manner described above, are given in Table IV.

TABLE IV.—The Eclipse Pressure Departures in Russia and in India.

Minutes	165	135	105	95	85	75	65
Russia (1889)	+·004	+·003	+·002	...	...	·000	·000
India (1898)	...	...	·000	−·002	−·002	−·001	·000
Minutes	**55**	**45**	**35**	**25**	**15**	**5**	**0**
Russia (1889)	·000	·000	·000	−·001	−·002	−·001	−·002
India (1898)	·000	+·001	+·001	+·001	+·002	+·003	+·003
Minutes	**0**	**5**	**15**	**25**	**35**	**45**	**55**
Russia (1889)	−·002	−·002	−·001	−·002	−·002	+·001	+·001
India (1898)	+·003	+·003	+·002	+·002	+·002	+·001	·000
Minutes	**65**	**75**	**85**	**95**	**105**	**135**	**165**
Russia (1889)	·000	−·001	·000	+·002	+·002	−·001	−·002
India (1898)	·000	·000	·000	·000	+·001	+·001	·000

The values in Table IV. are departures from a uniform change of pressure during the eclipse, and are given in thousandths of an inch. The middle of totality is indicated by 0 minutes, and the other numerals give the number of minutes preceding and following this epoch. As numerical values are not given in Mr. Eliot's report, these values were derived from his plotted curves (*Indian Meteorological Memoirs*, vol. xi. No. 2, plates xxi. and xxii.).

Mr. Eliot sought to eliminate the diurnal period from the pressur observed on the day of the eclipse by subtracting from the observe pressure the normal diurnal change on days with similar weather conditior There remained an abnormal increase of pressure during and followi the eclipse of about ·04 inch. This may have been due to the movem

of an anticyclone then covering India, or to some change in the diurnal curve produced by the eclipse. There were, however, variations in the rate of this increase, so that if a uniform rate of increase be assumed and subtracted from the observed increase, there are found a set of residuals such as those given in Table IV. If these residuals for Russia and India be plotted, they give curves similar to those in Fig. 11. However, while for India there is a preponderating maximum in the middle of the eclipse, for Russia this central maximum is only indicated by a flattening of the curve.

Prof. F. H. Bigelow, writing in *Science* of April 12 (N.S., vol. xiii. p. 589), says that the observations at 65 Weather Bureau stations for the eclipse of 1900 confirm the distribution of pressure which I have found for eclipses, and which is represented by the mean curve in Fig. 11.

The change of pressure is extremely minute, but there can scarcely be a doubt that it is real. Hence I am led to seek an explanation of the phenomenon, and I find the most satisfactory one in Ferrel's theory of cyclones with a cold centre.

Ferrel maintains, from theoretical considerations, that cyclones necessarily have an inner area of low pressure, surrounded by a ring of high pressure which Prof. W. M. Davis has named a "pericyclone." Ferrel also claims that a cyclone may have its origin either in a high temperature increasing toward a central area, or in a low temperature decreasing toward a central area. The one he calls a "cyclone with a warm centre," the other a "cyclone with a cold centre." Of cyclones with a cold centre he says:—

"If for any reason the central part of any given portion of the atmosphere of a somewhat circular form is maintained in any way at a lower temperature than the surrounding parts, and the temperature gradient on all sides is somewhat symmetrical, we have approximately the conditions which give rise to a cyclone. In this case it is readily seen that there must be a vertical circulation as in the ordinary cyclone, but that it is reversed, out from the centre below, and in toward the centre above, with a gradual settling down of the air in the interior to supply the outward current beneath. This vertical circulation, as in the case of the ordinary cyclone, gives rise to a cyclonic motion in the interior and an anticyclonic motion in the exterior part of the air under consideration; but in this case the gyratory velocity is greatest above and is less at lower altitudes, diminishing down to the earth's surface, where it is least. In the anticyclonic part the reverse takes place, the gyratory velocity being least above and greatest down near the earth's surface. . . . The conditions of a cyclone with a cold centre which are the most nearly perfect are those furnished by each hemisphere of the globe, as divided by the equator, in which the pole is the cold centre and the temperature gradient from the pole toward the equator is somewhat symmetrical in all directions from the centre. . . . The easterly motions in the higher latitudes and the westerly ones in the lower latitudes, in the one case, correspond to the cyclonic in the interior and the anticyclonic in the exterior part, and the belt of high pressure near the tropics to that of high pressure in the case of any cyclone with a cold centre. . . . The centre of a cyclone with a cold centre may, or may not, have a minimum pressure, according to circumstances. A certain amount of temperature gradient and of pressure gradient which is independent of gyratory motion, as explained in the case of the general circulation of the atmosphere, is necessary to overcome the friction in the lower strata and to keep up the vertical circulation upon

which the cyclone depends; and the pressure gradient, which depends upon the temperature gradient and is independent of the gyrations, may be such that the increase of pressure in the central part due to this cause may be greater than the decrease of pressure arising from the cyclonic gyrations, especially where surface friction is great."—*A Popular Treatise on the Winds*, pp. 337-339.

In § 72, to which Ferrel refers in the above quotation, he explains that the first effect of the low temperature at the pole is to contract the air and cause an overflow of the upper strata from the equator, so the tendency "would be to fill up a little, as it were, the polar region, the effect of which is to increase the pressure a little in the latter region, thus creating at the earth's surface and in the lower strata a gradient of pressure decreasing from the pole to the equator, which would cause a counter current in the lower strata."

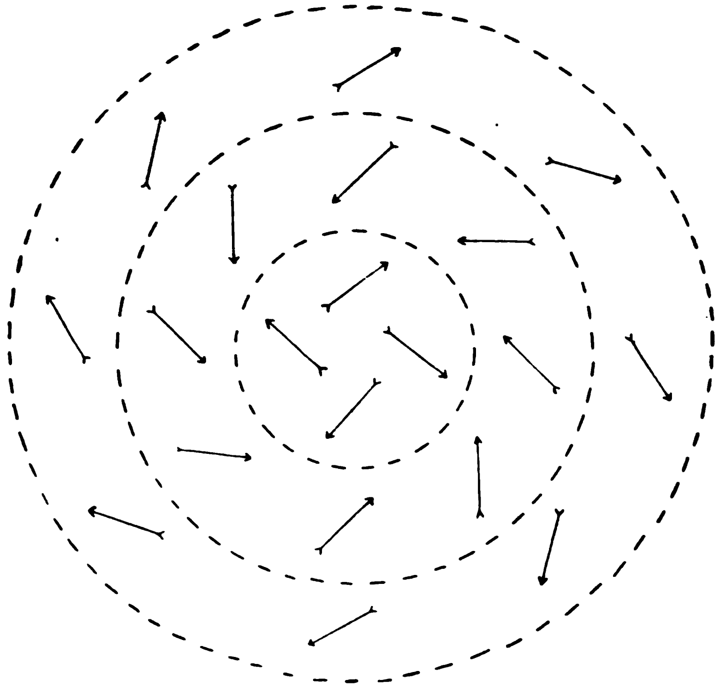


FIG. 12.

Fig. 12 illustrates the air circulation in Ferrel's polar cold-air cyclone. In this diagram the North Pole is made the centre of the circulation, and the successive circles represent the 60th parallel, the 30th parallel, and the equator. The diagram is derived from an illustration by Ferrel in the *American Journal of Science* (2 ser., vol. xxxi. p. 31). The diagram is intended to illustrate ideal conditions, and the influence of continents on the circulation is not considered. It differs from the eclipse cyclone chiefly by the fact that the inner circle of out-blowing winds is smaller than in the eclipse cyclone. Also the outer circle of out-blowing winds is not well indicated by the observations in the eclipse cyclone.

The Diurnal Cyclones.

The discovery of the eclipse cyclone has suggested that the fall of temperature due to the occurrence of night may also produce a similar cold-air cyclone. Combine this with a warm-air cyclone produced by the heat of day, and there is furnished a working hypothesis as to the cause of the two diurnal minima and maxima of pressure each day. In such a case, the minimum pressure at night would be the result of the cold-air cyclone, while the minimum pressure during the day would be the result of the warm-air cyclone, and the maxima of pressure between them would result from the overlapping of the pericyclonic rings surrounding the cyclones.

As a preliminary step in comparing theory with observation, the diurnal pressures at Blue Hill and Kew were averaged for three epochs of the year, viz. mid-winter, mid-summer, and the equinoxes. Blue Hill

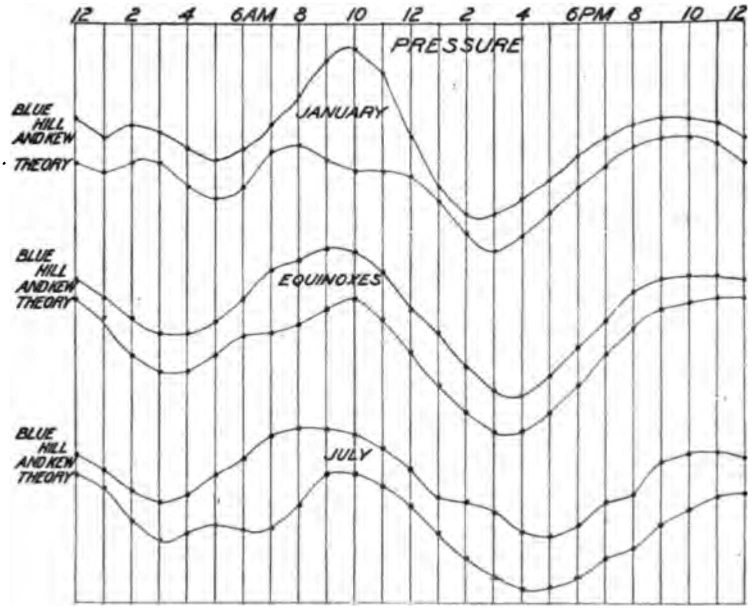


FIG. 13.

and Kew were selected because they were oppositely situated as regards the great continents and the Atlantic Ocean. It was hoped that the influence of these might thus be partly eliminated, and an approximation to a normal curve obtained. The numerical values are given in Table V. In order to form a theoretical curve for comparison with the curve plotted from the mean of the observations, two curves were constructed: (1) a symmetrical curve, modelled after that found in eclipses, to represent the cold-air cyclone of night, and (2) a symmetrical curve of pressure to represent the warm-air cyclone of day with a minimum pressure at the warmest time of the day and maxima of pressure about six hours preceding and following. The ranges in each case were taken from the observations. The hourly values read from these curves are given in Table VI. These values were added together and the results plotted

under the curves representing the observations in Fig. 13. It is seen that there is a general resemblance between the curves representing the

TABLE V.—DIURNAL DEPARTURES FROM MEAN PRESSURE AT BLUE HILL AND KEW IN THOUSANDTHS OF AN INCH.

	A.M.												
Hour	12	1	2	3	4	5	6	7	8	9	10	11	12
JANUARY.													
Blue Hill	0	1	3	3	-2	-6	-6	-2	-2	-6	-6	-2	3
Kew	3	0	0	0	0	0	3	8	10	10	7	3	-3
Mean	3	1	3	3	-2	-6	-3	6	8	4	1	1	0
APR. and OCT.													
Blue Hill	3	3	-2	-6	-6	-2	-2	-6	-6	-2	3	3	1
Kew	10	5	0	0	0	0	5	10	12	12	10	5	-2
Mean	13	8	-2	-6	-6	-2	3	4	6	10	13	8	-1
JULY.													
Blue Hill	2	2	-3	-5	-3	-1	-3	-5	-3	2	2	1	0
Kew	10	7	3	0	0	0	0	3	7	10	10	8	4
Mean	12	9	0	-5	-3	-1	-3	-2	4	12	12	9	4

	P.M.											
Hour	1	2	3	4	5	6	7	8	9	10	11	12
JANUARY.												
Blue Hill	3	1	0	0	0	0	0	0	0	0	0	0
Kew	-10	-16	-20	-16	-10	-3	3	7	10	10	8	3
Mean	-7	-15	-20	-16	-10	-3	3	7	10	10	8	3
APR. and OCT.												
Blue Hill	0	0	0	0	0	0	0	0	0	0	1	3
Kew	-10	-17	-22	-22	-17	-10	-2	5	10	12	12	10
Mean	-10	-17	-22	-22	-17	-10	-2	5	10	12	13	13
JULY.												
Blue Hill	0	0	0	0	0	0	0	0	0	0	1	2
Kew	-3	-10	-15	-18	-18	-15	-10	-3	4	8	10	10
Mean	-3	-10	-15	-18	-18	-15	-10	-3	4	8	11	12

observations and the theoretical curves. In fact, the resemblance at the times of the equinoxes is very close. Such differences as occur between the various curves might easily result from the irregular distribution of land and water over the world. If the theory be a true one, it is probable that every continent like Eurasia, every peninsula like Spain, and even every island, like the islands of Great Britain, has its own cold-air cyclone

of night and warm-air cyclone of day superimposed on the larger cold-air and warm-air cyclones of the world at large.

TABLE VI.—VALUES OBTAINED BY COMBINING ASSUMED VALUES OF PRESSURE IN SYMMETRICAL COLD-AIR AND WARM-AIR CYCLONES.

	A.M.												
Hour	12	1	2	3	4	5	6	7	8	9	10	11	12
JANUARY.													
Cold-Air	6	2	7	5	0	-1	4	12	19	31	31	18	-4
Warm-Air	4	-1	0	-2	-7	-11	-10	-5	3	10	15	15	5
Sum	5	0	3	1	-3	-6	-3	3	11	20	23	17	0
APR. and OCT.													
Cold-Air	8	3	-3	-6	-3	2	10	18	20	23	20	13	0
Warm-Air	8	3	-2	-7	-9	-8	-4	2	7	9	9	7	0
Sum	8	3	-2	-6	-6	-3	3	10	13	16	15	10	0
JULY.													
Cold-Air	5	1	-3	-6	-2	4	10	17	18	17	17	12	4
Warm-Air	8	4	0	-4	-4	-2	3	7	9	9	7	6	2
Sum	7	3	-2	-5	-3	2	6	12	14	13	12	9	3

	P.M.											
Hour	1	2	3	4	5	6	7	8	9	10	11	12
JANUARY.												
Cold-Air	-22	-29	-29	-23	-17	-10	-3	0	3	4	3	2
Warm-Air	-5	-11	-11	-8	-5	-1	3	5	6	6	5	2
Sum	-13	-20	-20	-16	-11	-5	0	3	5	5	4	0
APR. and OCT.												
Cold-Air	-7	-20	-26	-26	-21	-14	-6	2	6	6	6	5
Warm-Air	-6	-11	-16	-17	-13	-6	0	8	11	13	12	11
Sum	-6	-15	-21	-22	-17	-10	-3	5	8	9	9	8
JULY.												
Cold-Air	-5	-12	-17	-21	-21	-16	-10	-2	5	5	4	3
Warm-Air	-2	-6	-10	-14	-16	-15	-11	-3	5	10	10	8
Sum	-4	-9	-13	-18	-19	-16	-10	-3	5	7	7	6

NOTE.—These figures represent thousandths of an inch of pressure.

There is one feature of the observed and theoretical curves for winter to which I desire to call especial attention, and that is the third maximum about 2 a.m. in January, discovered by General Rykatcheff. In this feature the theoretical agrees perfectly with the observed curve. No theory of the diurnal changes in pressure has ever heretofore offered any

explanation of this phenomenon. According to the theory of cold-air and warm-air cyclones, it is produced by the ring of high pressure surrounding the cold-air cyclone. The reason is that in winter the greatest cold of night, about which the cold-air cyclone is made symmetrical, occurs later than 6 a.m. On the other hand, the warmest time of day occurs earlier in the day than in summer. The result is that the two diurnal cyclones are crowded together in high latitudes in winter, and three, instead of two, diurnal maxima of pressure are produced.

The facts, shown by observation, that the minimum diurnal pressure at night changes its position with the time of year, in accord with the change in time of lowest temperature, and that the minimum pressure of the afternoon changes its position in accord with the change in time of maximum temperature, are in perfect agreement with the theory here advanced.

The general facts brought out by such workers as Buchan, Rykatcheff, Angot, Hann, Schmidt, Curtis, and others in regard to the amount and kind of change of pressure in the diurnal period in different portions of the world can also be explained by the theory of two diurnal cyclones dependent on the diurnal range of temperature but modified by the amount of friction at the earth's surface.

1. Omitting the irregular influence of land and water, the greatest diurnal change of temperature occurs in the tropics and decreases to a minimum at the poles. As a consequence, the diurnal cyclones are central over the equatorial regions (see Fig. 15 [1]), producing the greatest diurnal range of pressure there, and the range decreases to a minimum in the polar regions.

2. The greatest range in the double diurnal change of pressure occurs at the equinoxes, because the contrast between day and night, taking the world as a whole, is then at a maximum. At the summer and the winter solstices the opposite poles have continuous day and night respectively, so that the diurnal oscillations are confined to a narrower zone than at the equinoxes. The diurnal cyclones and oscillations in pressure being dependent on the amount of daily change of temperature over the world at large, are, in consequence, of less intensity at the solstices than at the equinoxes.

3. Each large land surface tends to develop a system of diurnal cyclones of its own, and, in consequence, the diurnal pressure curves over the coast and over the interior of continents differ materially.

4. The intensity of the diurnal cyclones depends, in part, on local as well as on general conditions, and, consequently, the diurnal ranges in pressure respond in a certain degree to local changes in the diurnal ranges of temperature, as shown by Mr. R. H. Curtis.

5. The North Pole being on the edge of the general diurnal cyclone, as well as of the continental cyclones, the diurnal changes of pressure arise chiefly from changes in the intensity of the pericyclone. The pressure at the pole consequently oscillates in a phase opposite to that over the continents, being at a maximum when the general cyclone is reinforced by the warm-air cyclones of the continents, and at a minimum

[1] The data for these charts were derived from the *Report of the Voyage of H.M.S. "Challenger,"* vol. ii. 1889; *Untersuchungen über die tägliche Oscillation des Barometers*, von J. Hann, Wien, 1889 and 1892; and *Diurnal Fluctuations of Atmospheric Pressure at 29 Selected Stations in the United States*, by A. W. Greeley 1891.

when the afternoon minimum of the diurnal cyclone is over either ocean (*American Meteorological Journal*, vol. vi. p. 150).

6. Considering a vertical section of the atmosphere, the warm-air cyclone disappears above a certain neutral plane, and, at higher levels, is replaced by an anticyclone. On the other hand, the cold-air cyclone increases in intensity with increase of height, and, on account of its pericyclone, there is still a tendency to a double diurnal oscillation of the barometer, such as shown by harmonic analysis, though the chief effect is a single oscillation.

7. In the warm-air cyclone, the fall of pressure results from the rarefaction of the air by heat as well as from the movement of the air, so that over continents, where the range of the temperature is large, there is a marked minimum of pressure in the afternoon, as shown in the charts of Fig 15. In the cold-air cyclone, the fall of pressure depends on the centrifugal effect engendered, under the influence of the earth's rotation, by the motion of the air, and the fall of pressure tends constantly to be counteracted by an increase of pressure arising from an increase in the density of the air. Consequently, the friction of a land surface, especially in a mountainous region, tends to diminish the fall of pressure in the cold-air cyclone; so that it might easily happen, notwithstanding the larger change of temperature of the land, that the fall of pressure would be no greater there than over the sea where there was less friction. In valleys, where air circulation is almost entirely checked, the rise of pressure, due to the increased density of the chilled air, is the predominant feature at night, so that the diurnal pressure curve tends toward a single oscillation with a maximum at night and a minimum in the afternoon. Hence the diurnal barometric oscillations are partly the result of local, and partly the result of distant, general causes.

These various effects should be separately studied if possible. It is doubtful whether the harmonic analysis is the proper method of research, because there are two independent variables, the cold-air and the warm-air cyclones, which approach each other from the summer to the winter solstice, and then recede again.

The diurnal changes of the wind at stations on each side of the equator also indicate very strongly the existence of two diurnal cyclonic whirls, central in the equatorial region. Contrary to the motion of ordinary cyclones in temperate latitudes, these cyclones move from east to west. Their velocity of motion in the equatorial region is about 1000 miles an hour, but diminishes toward the poles. The upper chart in Fig. 14 shows the diurnal circulation at the earth's surface as derived from two stations, one north of the equator, the other south. In this chart the ordinates represent hours of the day and the abscissæ represent distances from the equator. The data are from observations at Blue Hill, Mass., lat. 42° 13′ N., long. 71° 7′ W., and at Cordoba Argentina, lat. 31° 25′ S., long. 64° 12′ W. (*Annals of the Astronomical Observatory of Harvard College*, vol. xxx. pt. iv. pp. 415 and 419). The directions of the arrows represent wind directions in the usual way, and the positions of the arrows in each case show the time of maximum frequency of each wind. Thus the greatest diurnal frequency of Southerly winds occurs at Cordoba at 7 a.m., and at Blue Hill between 7 and 8 p.m. There is also a second maximum frequency of Southerly winds at Blue Hill about

10 a.m. The wind arrows at Cordoba and Blue Hill are in general from opposite directions, and distinctly indicate a cyclonic circulation around two centres passing along the equator, and an outflow of air from high pressures intermediate between them. The lower chart in Fig. 14, headed "Upper Winds," shows the times of greatest frequency of each wind direction in the upper air between 2500 and 10,000 metres. These were determined from observations of clouds at Blue Hill and from hourly wind records on the Säntis in Switzerland. Cloud strata at three different

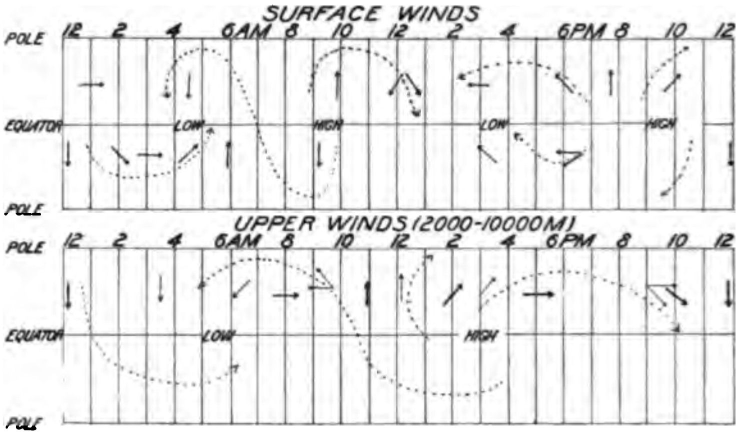


FIG. 14.

levels between 3000 and 10,000 metres above Blue Hill each gave a result similar to the other (*Annals of the Astronomical Observatory of Harvard College*, vol. xxx. pt. iv. pp. 415 and 419). This result is indicated by the heavy arrows in the chart. The observations on the Säntis at an elevation of 2500 metres are indicated by the light arrows in the same diagram. There are no observations at these heights south of the equator, but the observations north of the equator indicate a circulation very different from that found at the earth's surface. There is apparent at these heights only one cyclonic and one anticyclonic circulation. The low pressure in the cold-air cyclone of night persists at these levels, and probably with increased intensity, while the low pressure in the warm-air cyclone of day has been replaced by a high pressure and an anticyclonic circulation.

Cyclones and Anticyclones of Temperate Latitudes.

In the discussion of the records obtained by kites at Blue Hill ("Studies of Cyclonic and Anticyclonic Phenomena with Kites," *Blue Hill Meteorological Observatory, Bulletin No.* 1, 1899, also *Das Wetter*, Heft 4–8, 1899) it was shown that in the upper air there exist areas of low pressure in which the sky is clear, the air very dry and probably descending. The existence of these travelling areas of low temperature and low pressure in the upper air, producing cyclonic circulations of the wind extending to heights exceeding 10 kilometres, is even more strikingly brought out by Dr. Hergesell's discussion of the simultaneous records obtained by "ballon-sondes" in Europe ("Ergebnisse der internationalen Ballonfahrten," *Meteorologische Zeitschrift*, January 1900).

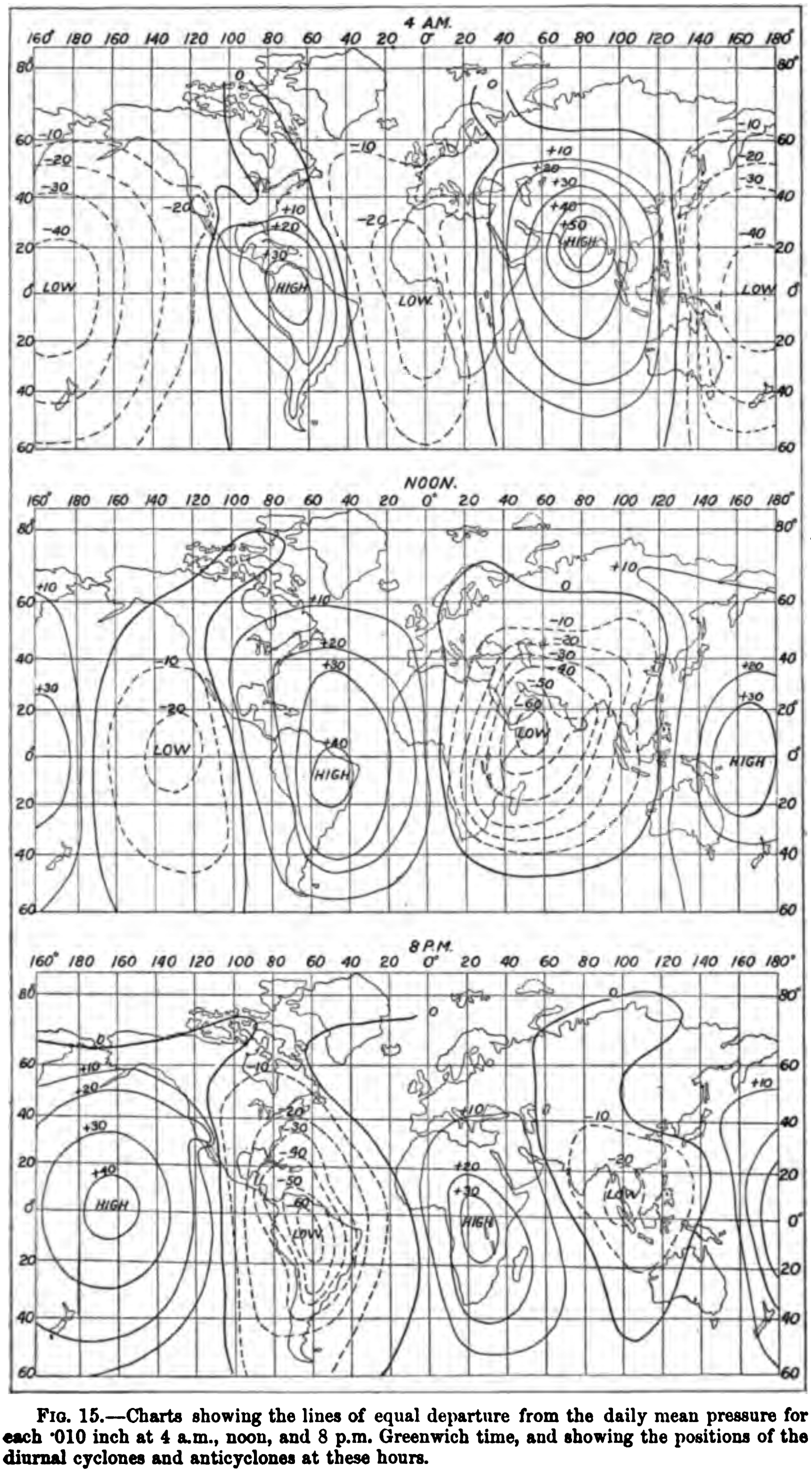


FIG. 15.—Charts showing the lines of equal departure from the daily mean pressure for each ·010 inch at 4 a.m., noon, and 8 p.m. Greenwich time, and showing the positions of the diurnal cyclones and anticyclones at these hours.

The discovery now, that even the slight and brief fall of temperature which accompanies an eclipse is sufficient to set an atmospheric circulation in motion, shows the importance of considering this aspect of the influence of cold air. Heretofore, meteorologists have considered mainly the influence of cold in producing an increased density of the air near the earth's surface and an increase of pressure at the ground resulting from an inflow aloft. But this inflow develops at the same time a cyclonic circulation which tends to lower the pressure and counteract the tendency to an increase of pressure at the ground. Ferrel's careful mathematical analysis shows also that a secondary result must be a ring of high pressure surrounding the upper-air cyclone with a cold centre.

This implies that there are two sources from which are derived our anticyclones: (1) increased density of the air due to cold; (2) the overlapping of the pericyclonic rings of adjacent cyclones. It is probable that each of these causes, singly or combined, are instrumental in producing the anticyclones of middle latitudes. There can scarcely be a doubt that the large permanent anticyclone over Siberia in winter is due to the increased density of the air from cold. It is over a large land surface where the outflow of the air is so retarded by friction that there is an accumulation of the air near the ground which cannot be reduced by the circulation of the inflow above. On the other hand, the observations on the Sönnblick discussed by Hann, the observations in balloons collected by the German meteorologists Assmann, Berson, and others, and the observations collected by Teisserenc de Bort with "ballon-sondes" appear to show that the air is warmer in anticyclones in Europe than in cyclones. Along this same line is the result of the investigation of Dines that the mean temperature at the earth's surface in England is not below normal in anticyclones (*Quarterly Journal of the Royal Meteorological Society*, 1897, vol. xxiii. p. 237). These facts suggest that the anticyclones of Europe are chiefly the result of the overlapping of the pericyclonic ring surrounding the cold-air cyclone of the upper air over Siberia (or the warm-air cyclone of India) and of the pericyclonic ring surrounding the warm-air cyclone of the North Atlantic.

By examining the diagrams of the eclipse cyclone, it will be seen that the pericyclone around it is entirely outside the area of depressed temperature. If a similar ring surrounds the cold-air cyclone in the upper air over Siberia, it might easily happen that the temperature would be above the normal in the irregular areas of maximum pressure formed within the pericyclone over Europe. On the other hand, the temperature within cyclones in Europe will probably be found to be higher than that of the atmosphere immediately surrounding them. The distribution of temperature, winds, etc., at the earth's surface in the surface cyclones of Europe are so similar to those in America that it is difficult to believe that there can be any difference in origin in the two places.

The observations with kites at Blue Hill show, without a single exception, that anticyclones in the eastern United States are colder than cyclones, up to at least 5000 metres. The positions of the centres of the anticyclones and cyclones are taken from the pressure reduced to sea-level. The coldest air for the latitude, however, is not at the centre of the anticyclone, but about midway between the anticyclone and the preceding cyclone. This fact appears to indicate that the anticyclone is

largely the result of the overlapping pericyclone between a travelling warm-air cyclone and a cold-air cyclone in the upper air.

General Conclusions.

The changes in the eclipse cyclone are very minute and feeble, but it will be seen from the foregoing that a consideration of the phenomenon has a very high value in the study of the atmosphere and in suggesting explanations of atmospheric phenomena. The eclipse may be compared to an experiment by Nature in which all the causes which complicate the origin of the ordinary cyclone are eliminated except that of a direct and rapid change of temperature. The results derived from the observations by eliminating the influence of other known phenomena give quantitatively the effects of a given fall of temperature near the earth's surface in a given time. They show that a fall of temperature is capable of developing a cold-air cyclone in an astonishingly short time, with all the peculiar circulation of winds and distribution of pressure which constitute such a cyclone. They show, furthermore, that a fall of temperature of the air does not act primarily to cause an anticyclone but a cyclone, and the anticyclone is a secondary phenomenon or rather a part of the cyclone.

The eclipse cyclone shows no apparent lag, or dynamic effect, due to the inertia of the air. To keep pace with the eclipse shadow, moving about 2000 miles an hour, the eclipse cyclone must have formed continuously within the shadow and dissipated in the rear almost instantly. In this way its motion may be considered to have a certain analogy to wave motion. Any given body of air, moving with the velocity of the eclipse winds, would not have moved more than 5 miles as a maximum during the passage of the eclipse. Hence all the changes of pressure must have been derived from the deflective influence of the earth's rotation acting on air moving this distance.

The eclipse cyclone also shows that cyclones do not necessarily drift with the atmosphere, but move with their originating cause, which, in the eclipse, had a progressive movement of about 2000 miles an hour.

Moreover, the eclipse cyclone has suggested a new theory of the diurnal barometric waves, and also suggested explanations of certain phenomena of ordinary cyclones and anticyclones.

The range of pressure between the minimum of pressure in each class of cyclones and the accompanying maximum of pressure is of about the following order of magnitude: (1) in the eclipse cyclone, ·01 inch; (2) in the diurnal cyclones, ·10 inch; (3) in the cyclones of temperate latitudes, 1·00 inch. The range of temperature in the three classes is about as follows: (1) in the eclipse cyclone, 5°; (2) in the diurnal cyclones, 10°, + 10° by day and − 10° by night; (3) in the cyclones of temperate latitudes, 20°. In the eclipse cyclone, the change is probably confined to the air within 300 metres of the earth's surface. In the diurnal cyclones, the change is confined to a stratum within 1000 metres of the earth's surface, as shown by observations with kites. In ordinary cyclones of temperate latitudes, the change of temperature extends to heights exceeding 10 kilometres, as shown by observations with "ballons-sondes."

In order to add to a knowledge of eclipse meteorology, observers of future eclipses should prepare to take much more accurate and detailed

observations than most of those of the past. Observations of wind direction to only eight points of the compass are inadequate for the study of the small changes which the eclipse causes in the prevailing winds. The direction should be recorded, if possible, by some such instrument as the Draper anemoscope, from which the mean direction can be read to degrees of azimuth. The wind velocity should be recorded in sufficient detail to be read to tenths of a mile; and the anemometer should be delicate enough, if possible, to record velocities of one mile an hour. The changes in pressure can probably be best observed by an air barograph with a large time-scale, such as that used at Toronto, which, being well protected from sudden changes in air temperature, would record the changes in atmospheric pressure during a brief interval very accurately, without necessarily giving correct absolute values of pressure. An aspiration psychrometer or a sling psychrometer are probably best for determining the temperature and humidity.

DISCUSSION.

The President (Mr. W. H. Dines) said that he thought the Society was much indebted to Mr. Clayton for bringing this interesting paper before it. At first sight it would appear as though cold air must produce a high barometer beneath it, but the extensive areas of low pressure that surround both the poles are facts which utterly contradict this idea. There can be no doubt that the low pressures at the poles are due to the centrifugal force of the Westerly winds that blow more or less in all temperate latitudes, and hence we must accept Ferrel's cold centre cyclone as a possible phenomenon. The whole question as put forward in this paper depended on the reality of the cyclonic circulation produced by the eclipse, and if that were accepted as a fact it had a most important bearing on theoretical meteorology. Mr. Clayton's supposition as to the cause of the double barometric daily oscillation was also very suggestive, but there was one awkward fact against it which he seemed to have overlooked. The double oscillation, opposed to the 24 hour period oscillation, was most marked near the equator, but owing to the absence of the directive tendency due to the earth's rotation, these regions were exactly those in which a cyclone could not be set up by the daily temperature variation. This was not necessarily fatal to the theory, but the distribution of pressure round a large cyclone, in one half of which the circulation was right handed and in the other left handed, needed further consideration.

Mr. J. Hopkinson remarked that in Table I. the divergence of the temperature and relative humidity from unknown values during the progress of the eclipse only was given. He thought it would be more interesting to have the actual temperature and humidity values, or at least these should be given either for the commencement and end, or the middle of the eclipse, at each place of observation.

Capt. M. W. C. Hepworth mentioned that in the region of the Trade Winds, the diurnal range of barometric pressure is more accentuated in strong winds, both in rise and fall, than in lighter winds. Great humidity is associated with the strong Trade Wind as a rule. It is usual for the Trade Wind to freshen after sunrise and to fall away again some hours before sunset. Generally there is an increase again after sunset, the wind decreasing for the second time between midnight and sunrise. What is the cause of this double rise and falling away of the wind? The rise of temperature may account for the freshening of the wind after sunrise, but how is the night increase to be explained? He thought Mr. Clayton's suggestions might throw some light on the subject.

Dr. R. H. Scott remarked that the diurnal range of barometric pressure in Alpine valleys was often considerable and comparable with that recorded near the equator.

The President (Mr. W. H. Dines), with regard to the preceding remark, said that he thought the large daily barometric oscillation that occurred in the Alpine valleys was easily explained. By the afternoon on sunny days the whole mass of air in the valley was thoroughly warmed by contact with the bottom and sides, and since the area was comparatively limited, there was no difficulty about the upper layers of air flowing off laterally as soon as they were raised by the expanded air beneath. Thus in the afternoon a much smaller mass of air lay over the valley, and hence the low afternoon minimum.

Mr. R. H. Curtis remarked that a study of the diurnal oscillation of pressure for short periods showed unmistakably the dominant part which temperature—and especially the diurnal variation of temperature, rather than its actual amount as shown by the thermometer—played in the causation of the phenomenon. On days of large temperature range the amplitude of the pressure oscillation became greatly increased, and under such conditions at Kew it sometimes fully equalled the normal oscillation of the tropics. It was however, very important to note that at the same time, at places not very distant from Kew, but having with other weather conditions a smaller range of temperature, the amplitude of the pressure oscillation frequently remained smaller than usual, and quite different in character. Of the many theories which had been from time to time put forward to explain this obscure phenomenon none were entirely satisfactory, but the novel and ingenious explanation now suggested by Mr. Clayton seemed to meet certain phases of it in a much more satisfactory way than previous schemes had done, and he desired to congratulate Mr. Clayton on having brought forward a theory so full of promise, and so well deserving of careful study and investigation.

Capt. A. Carpenter said that it was unfortunate that Mr. Clayton was not present, as the illustrations show an anticyclonic distribution for a fall of temperature, not cyclonic as stated by Mr. Clayton. With regard to the explanation of the increase of humidity during the eclipse, he always understood that descending currents were dry and not moist. Figures 6 to 9 were most interesting, showing a distinctly anticyclonic motion set up by a very slight fall of temperature. He should like to know what were the diameters of those circles in miles.

[Mr. H. H. Clayton, in a note to the Secretary, said, in reply to Mr. Dines, that the fall of pressure in the diurnal cyclones could not be due to air circulating around and across the equator, but, as in the case of the eclipse cyclone, the fall of pressure is due to the combined effect of areas of air at different latitudes moving only short distances. In the eclipse cyclone the maximum velocity of air-movement was about 2 to 3 miles an hour. In the diurnal cyclone, in the latitude of Blue Hill, the maximum velocity is about three times this amount, but the total wind-movement due to the diurnal cyclones is probably less than 100 miles in the 24 hours of the day. Mr. Dines is right in stating that the winds must circulate differently on the opposite sides of the equator. The left hand rotation is indicated by the afternoon winds at Cordoba, and the apparent exception in the early morning winds will probably not be sustained by other observations. Mr. Hopkinson will find the actual values of temperature, humidity, etc., in the publication referred to at the beginning of this paper. In reply to Capt. Carpenter, he said that the circles formed by the unbroken lines in Figs. 6 to 9 represent an area about 5000 miles in diameter. The anticyclonic circulation shown in the centre of the diagrams is a part of the cold air cyclone, and probably an essential part. In order to maintain the vertical circulation in the cyclone there must be an

outflow at the bottom dependent on the temperature, and this forms the surface anticyclone. This anticyclone has a large horizontal diameter when friction is large and a small diameter when friction is small.]

The Dynamics of Cyclones and Anticyclones.—Mr. John Aitken, F.R.S., has a very interesting paper on this subject in the *Transactions of the Royal Society of Edinburgh*, vol. xl. 1901. He begins by describing the formation of vortices in water in a vessel with a plug at the bottom, showing that none will arise unless a previous rotary motion, however slight, be given to the water, and then so violent a rotation sets in that the centrifugal force at the aperture overcomes, to a great extent, the hydrostatic pressure at that point. The explanation is then carried on to the formation of cyclones in steam, or in sal ammoniac vapour in a room, showing how some sort of a lateral draught is required to set the whole phenomena in action. In all cases a tangential movement is necessary.

Mr. Aitken then goes on to say that in ordinary weather work, attention is paid too exclusively to the cyclone, and not to the anticyclone. It is as if in considering a steam-engine we regarded only the boiler, and not the condenser. Neither cyclone nor anticyclone can exist without the other. He illustrates this interaction by two pairs of weather-maps for December 1898 and 1897 respectively. In the former the storm moved very rapidly, in the latter it did not. The reason of this difference he shows to be that the storm always moves forward along the direction of its steepest gradients, or of its strongest tangential force. These statements are well confirmed by the maps, and a table is given for ten cyclones in 1898 and 1899, showing rates of advance and character of gradients.

Dealing with the development of anticyclones over Spain in winter, he shows that if the temperature rises in the anticyclone it attracts the cyclone, if it falls it repels it. Mr. Aitken gives a novel explanation of the damp warm feel of the air in front of a cyclone ; he says the fall of the barometer draws the air out of the soil, and this is warm and moist. Ordinary soil contains one-sixth and sand one-fourth of their bulk of air, as proved by displacing the air in a closed box of soil with water.

In Part II. he describes the formation of cyclones in free air rising from a damp cloth laid on a plate heated by steam. It is best to have a vertical screen with a magnified saw, or rather comb, edge, and then the eddies form and chase each other across the plate. This is better shown by sal ammoniac vapour, the acid and ammonia being placed in watch-glasses. These experiments show that the direction and rate of the cyclone depend on the cross currents.

In the third note Mr. Aitken deals with the general theories of atmospheric circulation, as to what he calls the convectional and the dynamical, the former attributing all to the action of hot and cold air, the latter to the general motions of the atmosphere. Mr. Aitken thinks that he can distinguish between the dynamically and the convectionally driven cyclones. In the former the circulation is spirally *outwards*, in the latter spirally *inwards*. To prove this he refers to Bigelow's Reports on the International Cloud Observations. At only one level, that of the *strato cumulus*, is the circulation outwards. This is the level at which the circulation in both cyclones and anticyclones is most rapid, and by this test the evidence is entirely in favour of the convectional theory, and he shows that cyclones crossing the Atlantic tend to move northwards as the isotherms tend to move northwards, and to move eastwards if the isotherms trend in that direction.

THE SEISMOGRAPH AS A SENSITIVE BAROMETER.

By F. NAPIER DENISON, F.R.Met.Soc., Victoria, British Columbia.

[Read June 19, 1901.]

THE object of these brief notes is to bring before the Royal Meteorological Society, a description of certain terrestrial movements, which, after further and more general investigation, may prove not merely of scientific interest, but of practical value as an aid to weather forecasting, as at present carried on by the various Meteorological Services throughout the world.

Owing to the rapidly increasing importance and development of this western portion of Canada, the Dominion Government decided to establish a branch of the Central Meteorological Office, Toronto, at Victoria, B.C. I therefore had the privilege of being sent here from Head Office in September 1898.

At that time a Milne Seismograph was installed here, and has been in constant operation ever since. This instrument is mounted in the basement of a Government building, upon a concrete pier rising from the rock on the water's edge.

From that time until the present, bi-daily Weather Charts of the western portion of the continent have been made out from telegraphic weather reports received from Canadian stations extending eastward to Lake Superior, and from American ones throughout the Pacific slope and coast as far south as San Francisco. From these charts daily weather forecasts and storm-warnings have been issued for the benefit of this portion of Vancouver Island and the lower mainland.

Weather forecasting on this western seaboard, as on the British coast, is acknowledged to be more difficult than for more eastern portions of a continent, due to the easterly movement of all areas of barometric pressure. It has therefore been my keen desire, not merely to master the valuable though limited knowledge upon the subject already published by the Weather Bureaus of the States of Oregon and California, but to endeavour to obtain some premonition of approaching ocean storms before the coast barometers fall or the isobars upon the Weather Chart indicate its advent.

This has led to a minute study of atmospheric waves as recorded upon a sensitive Aerograph, which forms part of an instrument termed a "Hydro-aerograph"[1] which I devised and installed on the harbour. This instrument records both the primary and secondary tidal undulations, and atmospheric waves or billows. The study of these traces has proved of practical service, for often when the barometer is high along the coast, and the form of the isobars indicate nothing but high pressure, the "hydro-aerograms" will be considerably disturbed; that is, the barometric trace, though high, will be composed of waves of varying amplitude, and, as they represent small changes of pressure, cause the secondary tidal undulations also. These atmospheric waves are known to originate

[1] "The Great Lakes as a Sensitive Barometer," by F. Napier Denison, *British Association Report*, 1897; "The Hydro-aerograph," by F. Napier Denison, *British Association Report*, 1899.

frequently far above us, where masses of air of different densities, directions, and velocities come into frictional contact, and as the air is elastic their influence is felt on the sensitive instrument at the bottom of our "aerial ocean." These waves are frequently recorded during calm weather below, while the upper air is moving at high velocities, before the winds increase upon the surface of the earth.

The other method for obtaining indications of coming atmospheric changes forms the subject of these notes, which it is hoped will at least prove of sufficient merit to be read before this distinguished Society. Among other duties since my arrival here in September 1898, I have had the pleasure of attending to the Milne Seismograph, which is one of many now furnishing data for the seismological survey of the world which is being conducted by a Committee of the British Association.

As is customary at all similar seismological stations, the horizontal pendulum or boom is set in the meridian, and in this case has a time of vibration amounting to 18 seconds. Each week a new roll of photographic paper is put on the instrument and the old roll developed, then written up, including dates, hourly cut-offs, daily time error, and a register kept of all seismic or other phenomena recorded. The roll is then sent to Toronto, where it is again examined and a list of all recorded earthquakes made out and sent to Prof. J. Milne, F.R.S., Isle of Wight, who receives similar reports from all the other seismological stations. In attending to this instrument I have frequently found that in the course of twenty-four hours the boom would swing off the photographic paper, and to bring it into its proper position it was necessary to alter the levelling adjustment. It was also noticed that the movement was not confined to one direction, but travelled sometimes to the east and at others to the west; also that the amplitude of these swings was greatest during the winter months and least in summer.

In the spring of 1900, being desirous of obtaining more knowledge upon this subject, and suspecting it to be due to atmospheric causes, I started keeping a private daily record of these so-called "wanderings of the boom," in which the time of maximum east and west swings, and the exact position of boom at such times in millimetres, were entered. At first these movements appeared complex and confusing, although from the beginning a marked diurnal change (which Prof. Milne refers to in the *British Association Report*, 1897) was discernible; that is, a tendency for the boom to swing towards the west during the morning hours, then eastward till about or after sunset. This study became so interesting, that from the commencement of August 1900 I adopted a form of the following design for entering up these observations. Each page was devoted to one month, and each line to one day; the vertical columns were headed: "date," "max. swing west" (subdivided into two, for "time" and "amount"), "reading at cut-off" (subdivided into two, for "before" and "after"), then "max. swing east" (subdivided for "time" and "amount"), finally a "remarks" column.

By this method not only was it possible to ascertain the exact times and amplitudes of the diurnal movements, but to keep an accurate and continuous record in millimetres of the wanderings of the boom for each day, month, and year, and also its rate of travel.

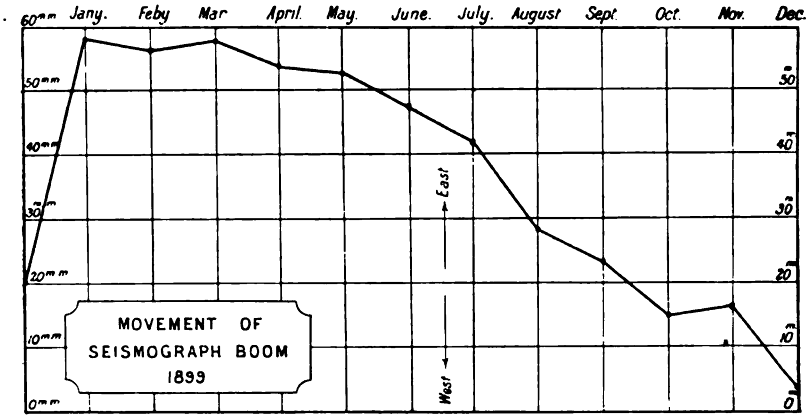
In order to endeavour to arrive at a definite reason for these curious movements, observations for the months of September, October, and November 1900 were plotted upon paper of 0·1 inch squares. The time-scale used was 2·4 inches per day, and 0·1 inch to equal one millimetre. Above this curve for each month was plotted the Victoria barometer from tri-daily observations, and surmounting this again was entered the tri-daily record of the direction and velocity of the wind and precipitation. It was then found that the diurnal change was most pronounced during periods of high barometric pressure, as is usual during the summer months, while shortly before the passage of areas of low pressure across the province from the Pacific, the diurnal change would be completely masked by the steady easterly movement of the boom. These plottings were then studied in conjunction with our bi-daily synoptic Weather Charts for the corresponding period. From this comparison the following results have been deduced:—That when the barometric pressure is high over the Pacific slope from British Columbia southward to California, while off the Pacific coast the barometer is comparatively low, the horizontal pendulum tends to move towards the eastward. This movement appears to be due to a distortion of the earth's surface, caused by the heavier air over the Pacific slope depressing the underlying land-surface below its normal position, while, on the other hand, the comparatively light air over the adjacent ocean tends to allow the sea and earth beneath to rise above its normal level; hence a horizontal pendulum as delicately poised as the one under discussion will, under these conditions, swing towards the region of greatest terrestrial depression, provided it be free to move in that direction. This theory of the earth's distortion under unequal atmospheric pressures is borne out when cases during these three months are taken when the barometer is high over the ocean and a trough of low pressure covers the Pacific slope and Rocky Mountains, then the boom is found to travel towards the westward and continue to do so until a change in the distribution of air pressure occurred.

Before proceeding further, I would mention that during this investigation I have been greatly encouraged to continue the subject by reading the accounts of previous work done in measuring the vibrations of the earth's surface by several European investigators: Mr. H. C. Russell, F.R.S., Sydney, N.S.W.; Prof. John Milne, F.R.S., Secretary, Seismological Committee; and Prof. G. H. Darwin, F.R.S.

In order to make a still more thorough study of this fascinating subject, I applied for, and, through the kindness of Mr. R. F. Stupart, Director of the Dominion Meteorological Service, received, the Victoria seismograms from January 1899 to July 1900. These I have carefully perused, and, by a time and millimetre scale, measured the diurnal changes and constant "wanderings" of the boom for each day during this period of 78 weeks. This occupied considerable time, as the total length of paper examined was over 2800 feet. These observations have been entered as those already described, and from the complete year 1899, which is all I have had time to prepare, the following results have been deduced.

To begin with, in taking the resultant monthly movements of the pendulum as given in the accompanying table, and examining the attached curve plotted from this table, we find a remarkable easterly swing

from January 1 to 31 of 38·6 mm., little change during February and March, then first a gradual westerly movement set in during the spring months, while throughout the months of June, July, August, September and October the rate of movement westward was very pronounced. In



November the westerly course was arrested and became to a small extent easterly, followed again in December by a marked westerly swing to the close of the year. The total westerly movement from the end of January to the end of December was 53·9 mm. In endeavouring to arrive at the cause of these seasonal movements it is useless to ascribe local influences, but to study the atmospheric conditions prevailing over the entire western portion of the continent and the adjacent Pacific Ocean.

TABLE I.—Showing resultant Monthly Movement of Boom during the Year 1899, commencing with 20 millimeters at 0 hours January 1.

Month.	Amount. mm.	Direction.	Month.	Amount. mm.	Direction.
January	38·6	East.	July	6·0	West.
February	1·7	West.	August	13·5	West.
March	1·4	East.	September	5·0	West.
April	4·4	West.	October	8·3	West.
May	1·0	West.	November	1·2	East.
June	5·0	West.	December	12·6	West.

Total annual westerly movement 53·9 mm.

Note.—Easterly movements correspond to increasing scale readings, and westerly to decreasing scale readings.

This has been done by carefully examining the Victoria bi-daily Weather Charts, which cover the above-mentioned land area, and also the monthly charts of normal barometric pressure published in the *Summary of the International Meteorological Observations* from 1878 to 1887 (Washington). Referring to the Victoria Weather Charts for January 1899, we find an abnormal amount of high barometric pressure prevailing over the Pacific slope from northern British Columbia southward to California, while off the coast at this latitude the normal winter low pressure remained constant. The combined influence of the heavier air over the Pacific slope and diminished pressure over the ocean probably

caused the abnormal easterly movement of the pendulum during this month. In February and March the movements both east and west were about equal to one another, which signified the constant eastward passage of both high and low barometer areas across this province, which was found, upon examining the charts, to be the case. As the season advances towards the summer we find the normal barometric pressure decreasing over the Pacific slope, while off the coast the permanent belt of high pressure moves northward from the latitude of California; at the same time the winter area of low pressure off the North Pacific coast gradually diminishes. These conditions doubtless account for the steady westerly swing throughout the summer months. In November the resultant of the two movements is easterly, and upon examining the weather charts for this month we find an almost constant area of high pressure over the Pacific slope and the Rocky Mountains, while off the coasts of the State of Washington and Vancouver Island the barometer remained low, which indicated the reappearance of the great winter low area over the North Pacific ocean. In December the prevailing movement was again westerly. The Weather Chart for this month indicated the passage of several high barometer areas up the coast to this province, with low barometric pressure over the Pacific slope, while on two occasions high barometer areas spread down the coast from northern British Columbia accompanied by cold waves and snow. These movements of high pressure from the north are of rare occurrence here, and probably affect the pendulum in the same way as the summer high pressure of this latitude does; hence we have a pronounced westerly movement of the boom during a winter month, when the reverse would have been expected under normal conditions.

In looking at the annual variation of the boom, one is struck with the remarkable westerly tendency shown, and how these observations bear out the statements of astronomers in England and Europe who have proved that the eastern piers of their transit instruments rise highest during the summer months.

In studying the pendulum's movements for each day of the year, one is impressed with the numerous interesting and complex subjects brought before him, each offering a large field for future investigation. Some of the chief points observed may, however, be worthy of presentation at this time.

It has been found that when an extensive storm area is approaching from the westward, and often 18 to 24 hours before the local barometer begins to fall, the pendulum swings steadily to the eastward, completely masking any diurnal fluctuations that might have existed, as the storm area approaches; and in the event of it being followed by an important high area, the pendulum will begin to swing towards the westward before it is possible to ascertain this area's position on the current Weather Charts. The principle already stated, that areas of heavy and light air cause a distortion of the earth's surface under which they prevail, is proved conclusively by types similar to the above illustration. During the summer months, when almost constant fine weather prevails in this latitude and no great barometric fluctuations occur, we find few days when the pendulum moves towards the eastward, while a westerly course becomes almost general. It is during this season, however, that the

diurnal change of a westerly swing in the morning and an easterly one towards evening becomes general, while the amplitude of these fluctuations often amounts to several millimetres.

Before concluding, I wish to state that in order to have an instrument near at hand which will indicate the distortions of the earth's surface which are constantly going on, I have recently constructed an instrument similar to the "Milne" Seismograph with the exception of it not being self-recording. This I have mounted on the top floor of the Post-Office which is close to the rooms of the Meteorological Office and adjoining my study. It is placed upon a piece of plate glass set in cement, which in turn caps the stone wall of the building. The height of this instrument above the ground is 60 feet, and 85 feet above the sea-level. To prevent air currents, it is carefully encased; while over the free end of the boom is glass, and under the boom is placed a millimetre scale with a range of 230. The time of vibration of the boom is 20 seconds. Eye readings are taken personally bi-hourly from 5 a.m. to 10 p.m. The few days' observations already obtained clearly demonstrate a pronounced diurnal change, and, when studied with the Weather Charts, bear out the theories already presented. It is hoped these eye observations will prove of material assistance, when studied with the Weather Charts, in making out the daily weather forecasts for the province.

To conclude, it is earnestly hoped that this imperfect attempt to demonstrate another valuable use for the Seismograph may lead to a further study of the subject by others more competent to solve the numerous and complex problems therein contained; for the time has come when, to improve the present systems of weather forecasting, a greater knowledge of the mysterious forces at work within our ocean of air must be obtained, and "The Seismograph as a Sensitive Barometer" is thought to be a practical aid in furthering these explorations. I sincerely trust, therefore, that the Royal Meteorological Society will favour the adoption of these instruments by meteorological offices and observatories, where they may be studied in conjunction with the existing atmospheric conditions.

DISCUSSION.

THE PRESIDENT (Mr. W. H. DINES) said that this was a very interesting paper, but that he did not think the explanation put forward by Mr. Denison for the motion of the boom could be the right one. A decrease of barometric pressure over the Pacific Ocean would not be accompanied by a change of pressure on the floor of the ocean, for the place of the air would simply be taken by water which would rise up under the barometric depression, and the pressure on the floor would remain the same. Also, were the motion of the boom due to such a cause it would inevitably follow the tides, which must produce far greater changes of pressure on the sea floor, than any change of barometric pressure could do.

[Prof. J. MILNE in a letter to the Secretary, said :—"That any instrument which responds to slight change in level, as for example certain forms of Seismographs, behaves like a barometer is well known. At Wilhelmshaven a barometric change of 1 mm. = 0·3″ change in the vertical, a quantity easily measured by horizontal pendulums which move a light spot 1 mm. for a tilt of 0·01 in. Not only will a horizontal pendulum respond to barometric change, but it responds to variations in several other meteorological elements. Here

at Shide (Isle of Wight) one pendulum sometimes swings West *before* and always during wet weather. An epitome of what I know about this subject is contained in *Seismology*, chapters xiii. to the end. On p. 246 will be found a curve, which has been extended, corresponding to that given by Denison. What I recognise as new in his work is that he has compared his Seismographic records with those of his Hydroaerograph, and with barometric gradients over large areas. What he has done is worth consideration and extension. Denison's success I take it to be largely due to the fact that his installation is on bed rock in the basement of a brick building, which he omits to mention. Had he been on wet alluvium, which is an unsuitable site for a variety of physical observations, he would have obtained results open to a variety of interpretations. At present his daily record is extended along 3 feet of paper. He ought for meteorological work to have an instrument recording on a band moving at about one-third this rate. I congratulate him on his paper, and regret that I cannot be present to hear it read."]

Prof. G. H. Darwin said that, while he was not convinced that the author had as yet established his conclusions, yet he thought that there was a future for work of this kind in Meteorology. He had himself estimated, about 20 years ago, the probable amount of the elastic yielding of the earth's surface under varying pressures, and had concluded that there were in existence instruments of sufficient delicacy to detect the changes in question. He had recently seen, at the Geophysical Observatory at Göttingen, a new form of Seismometer devised by Prof. Wiechert, which appeared to him much in advance of anything which had been constructed previously. The instrument, however, was expensive to construct, and involved the use of a very heavy weight. Dr. Wiechert showed him records which were to be explained as the tremors produced by the beating of heavy surf on the coast of Scandinavia. This conclusion had not yet been published, as a special series of simultaneous observations was in progress in Norway and at Göttingen, with the object of confirming a conclusion of which Dr. Wiechert himself already felt confident. Now if it is possible to obtain records of events happening at a distance of many hundreds of miles, it is not chimerical to hope that the earliest indications of meteorological changes may be obtained in a similar manner, and this is the end towards which Mr. Denison's work tends.

Dr. H. R. Mill said he was afraid that Mr. Denison's site at Victoria, B.C., was not a particularly happy one for the purpose of measuring seismic changes due to atmospheric pressure. There was a rapid increase in the depth of the water off the Pacific Coast, and an equally rapid rise of the land on the east to the plateau west of the Rocky Mountains. Hence there was a want of symmetry on the two sides that would make that portion of the crust imperfectly balanced. It would be interesting to study such changes of the horizontal pendulum on a great tract of land in the heart of a continent, say in Siberia. He also thought precipitation should be considered, as the mountains on the Pacific Slope were generally thickly covered with snow in the winter months, the deposition and melting of which might produce considerable effects. Possibly this, in part, accounted for the abnormal easterly movement of the boom in January.

Mr. R. Inwards thought that if this method were to be applied to any meteorological purpose, it would be necessary at least to have two instruments, one arranged with the boom in the meridian, like that of Mr. Denison, and the other with the boom at right angles to the first, so as to register oscillations and tremors in either direction. But it would be still better to have an instrument arranged on the principle of the Göttingen seismograph, which Prof. Darwin had described as registering movements in any azimuth whatsoever.

Mr. R. H. Curtis called attention to the statement of Prof. Milne in his letter, that he had found the boom of his instrument in the Isle of Wight swung

to the *westward* with the approach of atmospheric depressions from that direction, whilst Mr. Denison's instrument acted in the reverse way, and moved to the eastward, in the one case the boom moved *towards* the low pressure and in the other *away* from it. Possibly the relative distribution of land and sea at the two stations, and even the different geological character of the two districts, might explain this different action ; but if so, it was obvious that before practical use could be made of the seismograph as an aid in the prediction of storms, it would be necessary to determine for every station where one was erected the effect upon local conditions of the distribution of atmospheric pressure, so as to be able to interpret their reaction upon the instrument.

Mr. J. Hopkinson said that if it were a fact that the instrument would predict a fall of pressure from 18 to 24 hours in advance of that indicated by the ordinary barometer, it might be made of practical use in enabling warnings to be issued to our collieries and mining centres, similar to the storm warnings that were issued by the Meteorological Office. He thought that the United States and Canadian governments were very much more alive to the needs and claims of meteorology than was that of our own country, and that the Dominion Observatory at Toronto, which he had visited, and in which he had seen seismographs of different kinds, was, for purely meteorological purposes, apart from astronomical, far in advance of our own Greenwich Observatory. A National Seismological Observatory ought, he said, to be established somewhere near the centre of England, as in the neighbourhood of Birmingham, and it should be on Palæozoic rocks.

The Climate of Morocco.—In the sixth number for 1900 of the *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, Prof. Theobald Fischer gives the promised completion of his work on Morocco, recently published as an Ergänzungsheft of *Petermann's Mitteilungen*, in a paper on the climatology of that country. The names of the fifteen sections into which the paper is divided afford, perhaps, the best summary of its contents: observations, outline and relief of the region, pressure and winds, the coast region of cold up-welling water, thermal relations, rainfall, the extension of the coastal region, rainfall in the interior, the mountain region, temperature in the interior, dust-winds, temperatures of wells and springs, malaria, Tangier and Mogador as health-resorts. The observations at disposal are unfortunately very deficient, both as regards the number of stations and the length of time over which the observations extend ; but by a careful study of the existing material in relation to general conditions, Prof. Fischer is able to throw a good deal of new light on the climatology of Morocco. The mountain wall of the Atlas cuts the country almost entirely off from the Sahara region, and its climate is chiefly controlled by the subtropical high-pressure belt, and during summer somewhat south of it, hence the winter winds are West and South-west, especially towards the north, while in summer the North-east Trade reigns supreme. In the examination of the low temperature and high humidity of the coastal strip, due to up-welling of water off the coast caused by the winds, Prof. Fischer is able to make considerable use of ship observations, and his discussion of this part of the subject is of peculiar interest. The distribution of rainfall in Morocco is illustrated by a map, which shows a coast belt with an annual fall of 400 to 600 millimetres, giving an agricultural region of great fertility. A narrow belt of steppe land (rain 200 to 400 millimetres) lies between this and the Atlas region, in which the rainfall exceeds 800 millimetres, yielding an abundant supply of water for irrigation of the inner margin of the steppe.—*The Geographical Journal*, July 1901.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

May 15, 1901.

Ordinary Meeting.

William Henry Dines, B.A., President, in the Chair.

Miss Jane Charlesworth, Warwick House, Llandudno, was balloted for and duly elected a Fellow of the Society.

The following communications were read :—

1. "The Periodicity of Cyclonic Winds." By Rupert T. Smith, F.R.Met.Soc. (p. 261).

2. "An Account of the Bequest by the late G. J. Symons, F.R.S., to the Royal Meteorological Society." By William Marriott, F.R.Met.Soc. (p. 241).

June 19, 1901.

Ordinary Meeting.

William Henry Dines, B.A., President, in the Chair.

James Herbert Hugh Harrison, Public Hospital, Belize, British Hondúras;
Hormasjee Dinshaw Jassoobhoy, 3 Palli Road, Bandora, Bombay; and
Richard Llewelyn Jones, M.B., 3 Queen Square, Bath,
were balloted for and duly elected Fellows of the Society.

The President stated that the Symons' Memorial Fund had been transferred to the Society, and that the Council had that day accepted the trust.

The following communications were read :—

1. "The Eclipse Cyclone, the Diurnal Cyclone, and the Cyclones and Anticyclones of Temperate Latitudes." By H. Helm Clayton (p. 269).

2. "The Seismograph as a Sensitive Barometer." By F. Napier Denison, F.R.Met.Soc. (p. 293).

CORRESPONDENCE AND NOTES.

Study of Snow Crystals.—In the United States *Monthly Weather Review* for May 1901, Mr. W. A. Bentley gives a summary of twenty years' study of snow crystals. It was during the winter of 1884 that he secured his first microphotographs of snow crystals. Previous to that he had made some 300 drawings, but found these unsatisfactory. Photographs have been secured during every winter since 1884, and they now number over 800, no two alike. Nearly every great and famous winter storm since that date has furnished its quota of from four to twenty (and in one instance thirty-four) new forms to this collection. At the same time, observations have been made and data secured, while photographing the crystals, of the temperature; kinds and approximate heights of

clouds (when possible); the direction and rapidity of movement of various cloud strata; the direction and velocity of the surface winds; also changes in the forms of the crystals from hour to hour, as the different portions of each storm passed over the locality. The latter observations were made to ascertain whether there was any general law of distribution of the forms within the different portions of a storm. Differences in form of crystals deposited by local storms from those of general storms were also noted; as also the forms originating in, and peculiar to, each of the various cloud strata. These observations, and the data secured, indicate that the temperature and the humidity of the air at the earth's surface is a much less important factor than is generally supposed in determining the form and size of the crystals. We may easily conceive this to be the case, because at a given temperature, etc., at the earth's surface, the temperature and humidity of the air where the crystals form might vary greatly, one time from another, and would depend largely upon the height of the snow-producing clouds. The height of these varies greatly at different times, even when the temperature at the earth's surface remains the same. The data secured have not revealed the great mystery of the origin and cause of the differences in the forms of the nuclei; why columnar forms predominate at one time, tabular forms at another, or why both are sometimes found associated together. Much has been learned, however, of the conditions tending to modify their forms after the nuclear form is once organised. These conditions are many, the chief among them being the height, number, and vertical depth of the cloud strata, and the resultant variation in temperature, atmospheric pressure, and humidity due to these; the character of the storm, whether local or general; and the portion of the storm region from which the crystals come. To these must also be added the initial and subsequent movement of the crystals within the clouds. If, as must often be the case, the nuclear forms originating in the lower ascending clouds are carried upward to much greater heights by the strong ascending air currents, which often occur within such storms, until they become heavy enough to fall back through them, then the crystals will in all probability be greatly modified by passing through atmospheric strata varying so greatly in density, temperature, humidity, etc. That they are greatly modified by these flights in the clouds is clearly shown by the interior structure of many of the crystals outlining many of these transitory states. Thus, crystals whose nuclear form was originally nearly perfectly hexagonal, sometimes become partly triangular in outline, and *vice versâ*.

Nuclear imperfections are often corrected, and crystals become perfect in form. Conversely, perfect crystals become imperfect.

Tabular outgrowths in rare instances take place around a prismatic crystal, while spinous outgrowths often occur from and on a perpendicular with the main axis of tabular crystals. Crystallisation sometimes goes on also around the parts of a broken crystal.

Small tabular hexagons often acquire branching additions around their angles in the lower clouds and become of large size. Again, perfect crystals often receive additions of granular material in the lower clouds.

The most important facts of a general nature to be gleaned from these twenty years' study are these:—

1. That the greater number of the more perfect and beautiful tabular forms occur much more frequently in, and are confined almost wholly to, the western and north-western portions of great storms and blizzards.

2. That there seems to be a law of general distribution of the different forms, the columnar to one, the tabular and granular to others, with many varieties associated together in other portions of such great storms.

3. That this distribution is, with few exceptions, constant; that is, the same in nearly all storms.

Sufficient data have not as yet been collected to demonstrate beyond all doubt the fact that this law applies to all forms of crystals and to all storms alike.

The Influence of Winds upon Climate during the Pleistocene Epoch.—Mr. F. W. Harmer has contributed a paper on this subject to the *Quarterly Journal of the Geological Society* for August 1901. He calls it a "Palæo-meteorological" explanation of some geological problems. As a paper by Dr. Nils Ekholm on a similar subject, viz., "On the variations of the Climate of the Geological and Historical Past, and their Causes," appeared in our January number (vol. xxvii. p. 1), it will be interesting to give Mr. Harmer's "summary" in full.

"The winds are an important factor in determining the distribution of climatic zones. Deviations of the monthly or yearly isotherms from the normal are coincident generally with the direction of the prevalent winds. The influence of marine currents upon climate is indirect rather than direct. Winds and currents, however, act and react on each other.

"Changes of wind cause marked and sudden changes in the weather—daily, as in Great Britain, or seasonally, as in India; though the general direction of oceanic currents remains more or less the same. Permanent alterations in climate would also have resulted during past epochs had the course of the prevalent winds been permanently changed.

"The winds blow in a direction more or less parallel to the isobars; the latter group themselves round centres of high and low pressure, the higher pressure being, in the northern hemisphere, to the right of a man standing with his back to the wind. Anomalous weather is due to some unusual arrangement of the areas of high and low barometric pressure. Similarly, former cases of anomalous climate can only have occurred when the meteorological conditions were favourable.

"At present the continental areas are hotter than the ocean during the summer, and are therefore cyclonic; they are colder in winter, and are then anticyclonic. Cyclones and anticyclones are necessarily mutually complementary, as are the troughs and crests of waves. The baric conditions of the oceans at different seasons are usually of a more or less opposite character to those of the neighbouring land-tracts.

"During the Glacial Period, the regions covered by ice might have been, to a greater or less extent, anticyclonic at all seasons; low-pressure systems prevailing at the same time over the warmer regions immediately to the south of them, and over the adjoining oceans. The relative positions of areas of high and low barometrical pressure, the direction of the prevalent winds, and the consequent distribution of climatic zones, would in such a case have differed from those of the present time. Oceanic winds, with copious rainfall, may have prevailed over regions now arid, and mild winters where they are now excessively severe.

"The teachings of geology will thus throw light on the meteorology of the past, and meteorology may explain the causes of former cases of anomalous climate. At present, for example, dead shells are but seldom found on the eastern shores of Norfolk and Suffolk, though they are constantly driven on to the Dutch coast by Westerly gales. The extraordinary profusion of such débris in the Upper Crag-beds of East Anglia, the littoral deposits of the North Sea in Pliocene times, suggest that Easterly gales were more common there at that period than they are now.

"The prevalence of strong Westerly winds in that region at present is due to the fact that the centres of cyclonic storms approaching Great Britain from the Atlantic, pass to the north or north-west. When an anticyclone exists to the north, which is not often the case during the winter, cyclones take a more

southerly course, and Easterly gales are experienced in the Crag district. Such a state of things existed, not improbably, in the later Pliocene Epoch, as glacial conditions may have by that time established themselves, to a greater extent than at present, upon the Scandinavian highlands.

"During the existence of anticyclonic conditions over the European ice-sheet at the period of its maximum extension, when lower pressures prevailed in the warmer areas south of it, cyclonic storms may have passed farther south than they do at present, bringing oceanic winds over the Saharan desert, which, it is known, formerly enjoyed a more humid climate.

"The abundance of the mammoth in Pleistocene times along the shores of the Polar Sea (where no trees can grow at present, owing to the excessive severity of its winter climate), may have occurred during the existence of an ice-sheet in North America, when a different statistical alignment of the Behring Strait cyclone, due to the more northerly position of the American anticyclone at that period, brought mild South-easterly winds from the Pacific over Northern Siberia, ameliorating its winter climate, just as the prevalent alignment of the Icelandic cyclone now carries mild South-westerly winds over Great Britain and Scandinavia, and thence into the Polar regions at that season.

"The alternate humidity and desiccation, during the Pleistocene Epoch, of the now arid basin of Nevada, where great lakes formerly existed, may have coincided with successive alternations in the alignment of the isobars, caused by the advance or retreat of the American ice-sheet, originating at one time moist oceanic, and at another dry, winds from the land, over the region in question.

"It is difficult, however, to restore hypothetically the meteorological conditions of the Pleistocene Epoch, on the theory that the maximum glaciation of the Eastern and Western Continents was contemporaneous. At present the influence of the Gulf Stream and the South-westerly winds indirectly caused by it carries a comparatively warm climate northward during the winter over the British Isles and Scandinavia into the Polar Circle, but no permanent ice-sheet could have existed in those countries under such circumstances. The view that the maximum glaciation of North America and Europe was contemporaneous, involves the admission that an enormous anticyclone extended more or less prevalently at that epoch from the Pole southward over a considerable portion of both continents at the same time, during the winter, and to some extent in summer. Such a state of things, however, if even it could have been for a time established, would have been meteorologically of a most unstable character, tending to produce at all seasons atmospheric disturbance in the Atlantic, with prevalent Southerly and South-westerly winds to the east of the cyclonic centres, flooding North-western Europe with warmth. Conditions similar to those which may have prevailed during the maximum glaciation of North America occurred during the winter of 1898-99, when the weather was persistently and excessively cold in America, and abnormally warm in Europe: temperatures of $-60°$ Fahr. were recorded on the same day in the one, and $70°{\cdot}5$ Fahr. in the other; the former being due to cold winds from the Polar regions, and the latter to warm winds from the subtropical zone, strictly complementary to them, and due to the same cause.

"The Northerly winds on the one side, either of a cyclonic or an anticyclonic centre, are the necessary equivalent of the Southerly winds on the other. It is not possible, therefore, that the Northern Hemisphere could have been wholly cold at one stage of the Glacial Period, or wholly mild at another. The alignment of the isotherms and the distribution of climatic zones were probably at least as irregular then as at present, arctic and temperate conditions co-existing in different areas at the same latitude. Indeed, if the disturbances of the atmospheric equilibrium in temperate regions were more marked at that period,

as seems probable, the contrasts in climate may have then been even greater than they are now.

"No such meteorological difficulties arise if we adopt the hypothesis that the more important glacial and interglacial variations of climate may have alternated in the Western and Eastern Continents. Minor changes, however, may have been of more local distribution.

"The winter temperature of Labrador (one of the North American centres of ice-accumulation during the glacial period) is as cold, and the annual rainfall as great, as in Greenland at the present day ; the summers are, however, warm in the former, owing to the Southerly winds which there prevail intermittently at that season. Were it not for this, Labrador might even now resume its glaciated condition.

"The accumulation of an ice-sheet in North America would not necessarily have prevented Western Europe from enjoying a climate as temperate as that of the present time ; it might even have raised the winter temperature of the latter region. On the other hand, it seems probable that the effect of the anticyclone on an ice-sheet, extending eastward from Greenland over Great Britain, Scandinavia, and Northern Europe, would have been to change the prevalent alignment of the low-pressure system of the North Atlantic, producing warm South-easterly winds in Labrador and New England during the winter, instead of the Northerly winds now prevalent there. The alteration in the direction of the winds would have tended, moreover, to divert the warm surface-currents of the North Atlantic from the European to the American coast.

"The maximum glaciation of Great Britain could only have taken place at a time when the Icelando-British channel was closed, either by an elevation of the submarine ridge connecting those countries, or by its being blocked with ice, or perhaps under the influence of both causes combined. There is evidence to show that alterations in the level of this region did occur during the glacial period. It is possibly to differential earth-movements of elevation and subsidence in different parts of the Northern Hemisphere that the suggested shifting of glacial conditions from one side of the Atlantic to the other may have been due.

"The views here taken afford a simpler explanation of the geological facts than those usually adopted. Instead of supposing that the climatic changes of the great ice age, several times recurrent at intervals of a few thousand years only, were due to astronomical or extra-telluric causes, it is suggested that the average temperature of the Northern Hemisphere during the Pleistocene Epoch being, from some hitherto unexplained cause, lower than that of our own era, conditions of comparative warmth or cold may have been more or less local, as they now are, and that the more important variations of climate during that epoch may have affected the great continental areas at different periods."

The Circulation of Salt.—At the recent meeting of the British Association at Glasgow Mr. William Ackroyd read an interesting paper on the circulation of salt and its geological bearings. He showed that during storms salt was driven from the sea far on to the land, dissolved by rains, and carried back to the sea ; and in calm times the same phenomenon was also in progress. Various computations had been made of the amount of salt deposited on the land in this manner, from 24·59 lbs. per acre per year at Rothamsted to 641 lbs. at Penicuik. He estimated that during 1900-1901 there were 172·3 lbs. per acre per year deposited on the Pennine Hills, nearly midway between the Irish Sea and the German Ocean, at an altitude of over 1000 feet above sea-level. It was shown that for the millstone grit and the limestone districts of Yorkshire, as well as for a belt of American coast some 200 miles broad, this cyclic sea salt formed fully 99 per cent of what was carried to the seas by the rivers, though Prof. Joly, in his estimate of the age of the earth, only allowed 10 per cent.

Meteorological Observations taken at Majunga, Madagascar, 1900.—Referring to previous reports of the meteorological observations taken by me at Majunga, Madagascar,[1] I now send the results for the year 1900. Owing to the French expedition in 1895-96 the observations had to be discontinued as the Observatory was occupied by the military authorities, and it was not till 1898 that the house was reconstructed and all the instruments replaced. The yearly values for 1892-93, 1893-94, and April to December 1894 are given for the purpose of comparison, also a few of the observations taken in 1899.

Pressure.—The highest observed was 30·289 ins. on July 1, at 11 a.m., and the lowest 29·739 ins. on March 16, at 5 p.m., with heavy rain and thunderstorms—the lowest reading previously recorded being 29·450 ins. during a cyclonic storm on February 4, 1899, at 5 p.m.

Results of Meteorological Observations made at Majunga, Madagascar.
Lat. 15° 43′ 0″ S., Long. 46° 19′ 15″ E. Height, 134 ft. above sea-level.
(*In English and French measures.*)

1900.	Pressure at Sea-Level.				Temperature.											
	11 a.m.		5 p.m.		11 a.m.		5 p.m.		Means.				Extremes.			
									Min.		Max.		Min.		Max.	
	Ins.	Mm.	Ins.	Mm.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.	F.	C.
					°	°	°	°	°	°	°	°	°	°	°	°
January .	29·995	761·8	29·883	759·0	85·0	29·3	83·2	28·3	74·7	23·6	88·6	31·4	71·0	21·6	94·3	34·5
February .	29·976	761·4	29·887	759·1	83·6	28·6	81·6	27·4	74·6	23·6	86·8	30·4	71·5	21·9	93·6	34·2
March .	30·003	762·0	29·898	759·4	86·4	30·2	84·2	28·9	75·4	24·0	89·8	32·1	72·0	22·2	94·6	34·7
April .	30·051	763·3	29·939	760·4	87·1	30·5	84·3	28·9	73·8	23·2	90·6	32·5	70·0	21·1	95·2	35·0
May . .	30·106	764·7	30·005	762·1	84·3	28·9	86·4	30·2	71·6	22·0	88·9	31·5	68·3	20·1	92·8	33·7
June . .	30·164	766·1	30·081	764·0	81·2	27·2	79·1	26·1	66·8	19·2	85·1	29·4	64·0	17·7	89·2	31·7
July . .	30·187	766·7	30·089	764·2	80·1	26·6	78·8	25·9	65·1	18·3	85·5	29·6	62·3	16·7	88·6	31·4
August .	30·174	766·4	30·c87	764·2	81·7	27·5	77·5	25·2	66·2	18·9	86·9	30·4	63·0	17·1	92·3	33·4
September.	30·164	766·1	30·063	763·6	83·3	28·4	78·6	25·8	69·4	20·7	88·8	31·5	65·0	18·2	95·0	34·9
October .	30·146	765·7	30·013	762·3	85·1	29·4	81·0	27·1	71·3	21·8	91·6	33·2	68·0	20·0	96·2	35·6
November.	30·088	764·2	29·947	760·6	85·1	29·4	81·7	27·5	74·5	23·5	90·1	32·2	70·1	21·1	95·0	34·9
December.	30·054	763·3	29·934	760·3	84·6	29·1	83·0	28·2	75·7	24·2	91·6	33·1	72·0	22·2	97·6	36·4
Year . .	30·092	764·3	29·985	761·6	84·0	28·8	81·6	27·4	71·6	22·0	88·7	31·4	62·3	16·7	97·6	36·4
April 1892-Mar. 1893	30·028	762·7	29·958	760·9	84·5	29·0	82·2	27·9	70·6	22·0	88·7	31·4	60·0	15·5	98·8	37·0
April 1893-Mar. 1894	30·049	763·2	29·972	761·3	83·9	28·7	82·0	27·8	71·0	21·6	87·2	30·6	61·1	16·0	95·5	35·2
April-Dec. 1894	30·065	763·6	29·988	761·7	83·5	28·5	81·6	27·6	70·4	21·3	87·1	30·1	62·0	16·6	96·5	35·7
Jan.-Dec. 1899	30·000	762·0	29·972	761·3	...	...	...	...	71·0	21·6	87·8	31·0	...	...	...	...

Temperature.—The mean values did not vary from those previously given to any appreciable extent. In June and July only did the extreme maximum fall below 90°, while during 6 months the extreme minimum exceeded 70°. The coldest month of the year was July, with a mean temperature of 79°·4, and the hottest, April, with 85°·3, which is the highest as yet recorded.

Radiation.—Five grass minimum thermometers have been sent at times from London, but all have been broken in the post in transit. The highest observed maximum in sun (black bulb *in vacuo*) was 167°·3 on November 8.

Rainfall.—Rain fell on 71 days on the year, which is about the average,

[1] *Quarterly Journal of the Royal Meteorological Society*, vol. xxi. p. 21, and vol. xxii. p. 69.

1900.	Humidity.										Solar Radiation.		Rainfall.			
	Depression of Wet Bulb.				Tension of Vapour.				Relative Humidity.							
	11 a.m.		5 p.m.		11 a.m.		5 p.m.		11 a.m.	5 p.m.	Extreme.		Total.		Greatest Fall.	
	F.	C.	F.	C.	Ins.	Mm.	Ins.	Mm.	%	%	F.	C.	Ins.	Mm	Ins.	Mm.
January	6.1°	3.3°	4.7°	2.6°	.867	22.0	.883	22.4	72	78	162.0°	72.2°	14.79	375.0	4.30	109.3
February	4.7	2.6	3.4	1.9	.895	22.7	.896	22.8	78	83	149.8	65.4	17.82	452.6	3.99	101.4
March	7.4	4.1	5.2	2.9	.853	21.7	.887	22.5	68	77	159.0	70.5	6.90	175.2	3.35	85.1
April	11.4	6.3	7.1	3.9	.700	17.8	.801	20.2	54	68	149.5	65.2	0.71	18.0	0.65	16.5
May	11.8	6.6	12.1	6.7	.617	15.7	.697	17.7	52	62	145.2	62.8	...	...	...	...
June	12.8	7.1	9.8	5.5	.519	13.2	.584	14.8	49	58	137.3	58.4	...	...	...	...
July	13.2	7.3	9.8	5.5	.485	12.3	.569	14.5	47	59	143.5	61.9	0.02	0.5	0.02	0.5
August	13.7	7.6	7.4	4.1	.502	12.8	.620	15.8	47	66	141.0	60.5	...	...	...	...
September	12.7	7.0	7.0	3.9	.563	14.2	.654	16.6	50	66	148.0	64.4	...	...	...	...
October	13.3	7.4	7.9	4.3	.584	14.8	.686	17.4	49	64	152.3	66.7	0.32	8.1	0.25	6.4
November	10.7	5.9	6.5	3.5	.676	17.2	.758	19.3	56	70	167.3	75.0	5.37	136.4	1.23	33.8
December	11.3	6.3	6.9	3.8	.642	16.3	.771	19.6	54	69	158.0	70.0	6.12	155.4	2.15	54.6
Year	10.8	6.0	7.3	4.0	.659	16.7	.734	18.6	56	68	167.3	75.0	52.05	1321.2	4.30	109.3
April 1892-Mar. 1893	12.3	6.8	8.9	4.9	.610	...	.675	...	51	61	...	...	57.26	1440.8	4.13	104.9
April 1893-Mar. 1894	12.3	6.8	9.0	5.0	.600	...	.668	...	51	60	...	...	51.91	1304.1	5.43	137.8
April-Dec. 1894	12.9	7.1	9.2	5.1	.573	...	.655	...	50	60	...	...	26.05	661.6	4.69	119.2
Jan. - Dec. 1899	...	...	...	...	...	...	...	...	51	60	...	...	39.96	1001.5	...	...

1900.	Amount of Cloud.		Weather. No. of Days of					Wind. No. of Observations of								
	11 a.m.	5 p.m.	Rain.	Thunder-storm.	Clear Sky.	Overcast.	Gales.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
January	5.8	8.2	15	8	1	9	0	4	2	2	2	0	4	7	25	15
February	6.4	7.7	20	7	3	16	0	5	9	0	1	0	2	7	18	14
March	4.2	6.4	13	5	6	5	0	0	7	2	3	6	2	5	24	12
April	2.2	2.1	3	2	18	0	0	0	3	6	8	5	2	16	10	9
May	1.4	1.6	0	0	23	0	0	0	2	11	20	7	1	6	5	10
June	0.9	2.6	0	0	19	1	0	0	2	5	16	8	2	9	6	11
July	0.6	2.0	1	0	22	1	0	0	4	15	13	7	1	9	8	4
August	0.4	2.5	0	0	22	0	0	1	1	10	10	3	0	7	20	10
September	1.1	3.1	0	0	15	0	0	4	7	2	1	0	0	10	29	7
October	2.4	1.8	3	1	15	0	0	8	3	3	2	0	1	7	33	4
November	4.4	5.7	9	2	7	4	0	6	5	1	0	2	2	5	23	16
December	5.8	6.6	7	6	0	6	0	7	6	2	6	3	0	6	24	8
Year	3.0	4.2	71	31	151	42	0	35	51	59	82	41	17	94	225	120
April 1892-Mar. 1893	3.1	3.6	71	94	171	45	2	136	59	69	78	54	80	62	171	121
April 1893-Mar. 1894	4.0	4.3	75	88	127	78	0	59	42	66	149	46	49	37	62	20
April-Dec. 1894	3.4	4.1	45	45	119	54	2	20	23	23	158	34	51	28	201	12
Jan. - Dec. 1899	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

while that of December was below; between March and November, *i.e.* seven months of the year, there was practically no fall of rain that was of any real value for agriculture or grazing purposes, consequently there was a heavy death-rate among the cattle, but locusts or crickets increased innumerably, and even since the heavy rainfall are a terrible scourge to the country. The heaviest rainfall recorded was 4·30 ins. on January 20.

Hygrometry.—There has been much less difference between the readings of the dry and wet bulbs than the average, which, I think, can be attributed to the prevalence of North-west winds bringing humidity from the sea, and also to there being so much calm weather, no less than 120 observations having been recorded.

Thunderstorms.—Only 31 were recorded, whereas 90 is the average, and the severity of even these was much less than those experienced in previous years.

During the year 1899 only a few observations could be taken daily.—STRATTON C. KNOTT, F.R.Met.Soc., British Vice-Consul.

RECENT PUBLICATIONS.

Annales du Bureau Central Météorologique de France. Publiées par E. MASCART, Directeur. Année 1898. 3 vols. 4to. Paris, 1900.

Part I. is devoted to Memoirs and contains the following articles:—(1) Report on the Work of the Bureau Central Météorologique, by Mons. Bouquet de la Grye, President of the Council; (2) Thunderstorms in France and the State of the Atmosphere during 1898, by Mons. E. Fron; (3) Magnetic Observations made at the Parc St. Maur, by Mons. T. Moureaux; (4) Magnetic Observations made at the Perpignan Observatory, by Mons. P. Cœurdevache; (5) Magnetic Survey of France to January 1, 1896, by Mons. T. Moureaux; (6) On the Diurnal Range of Horizontal Currents, by Mons. C. Goutereau; and (7) Migration of Birds in France: Times of the First Song of the Cuckoo, 1881-95, by Mons. A. Angot.

Part II. contains the results of the second order observations made at the following number of stations:—France, daily 17, monthly 173; Algeria, daily 10, monthly 38; Colonies, daily 13, monthly 40.

Part III. contains the daily observations of rainfall *in extenso* from 2032 stations in France.

Annuaire de la Société Météorologique de France. April and May 1901.

The chief articles are:—"La température à Paris pendant les cinquante années 1851-1900": par Alfred Angot (3 pp.). Monsieur Angot has the records of Parc St. Maur since 1873, and for the previous years he interpolates from the figures for the Observatoire and from Versailles (Dr. Béringy). These last two series overlap Parc St. Maur, and so he gets a correction so as to build up 50 years.—"Etude sur l'hydrologie du bassin de l'Adour au point de vue de l'annonce des crues": par M. Georges Lemoine (29 pp.). The author gives a long description of the principal floods which have been reported since 1878, when the Adour Commission was started; but he concludes by saying that a more strictly scientific system should be followed if improvements are to be obtained in the system of flood warnings.

British Rainfall, 1900. On the Distribution of Rain over the British Isles during the year 1900, as observed at about 3500 stations in Great Britain and Ireland, with Articles upon various branches of Rainfall Work. Compiled by H. SOWERBY WALLIS and HUGH ROBERT MILL, D.Sc., LL.D. London, 1901. 8vo. 72 + 254 pp.

This work follows on the same lines as its predecessors, although it is no longer called "Symons's" after the founder. The number of stations furnishing complete records was 3493. The year 1900 was on the whole wetter than the average of the 10 years 1880-89; only a little in the case of England and Wales, but to a very marked degree in Scotland and Ireland. The largest rainfall was 207·10 ins. at Ben Nevis Observatory, and the least 17·23 ins. at Great Leighs, Essex.

In addition to the usual information and tables of rainfall, the volume contains two papers by Dr. Mill, viz. (1) "The Ilkley Flood of July 12th"; and (2) "The Development of Rainfall Measurement in the last Forty Years."

Congrès International de Météorologie. Paris, 1900. *Procès-Verbaux des Sciences et Mémoires.* Publiées par M. ALFRED ANGOT, Secrétaire Général du Congrès. Paris, 1901. 8vo. 272 pp.

The Congress was held at Paris from September 10 to 16, 1900, in connection with the International Exhibition. The officers of the Congress were: President, Prof. E. Mascart; Vice-Presidents, Dr. H. Mohn (Norway), Prof. A. Rücker (England), and Gen. M. Rykatchef (Russia); Secretary, Mons. A. Angot.

This volume contains the proceedings at the general meetings of the Congress, and also of the Committees on meteorological telegraphy, solar radiation, clouds, terrestrial magnetism, and scientific aerostation or ballooning. In addition there are 35 papers by various authors—mostly well-known meteorologists—printed *in extenso.*

The members of the Congress paid a visit to Mons. Teisserenc de Bort's Observatory at Trappes, where they witnessed some kite-flying, and were also photographed. A reproduction of this photograph is included in the volume.

Handbook of Public Health, Laboratory Work, and Food Inspection. By O. W. ANDREWS, M.B., D.P.H., Staff-Surgeon, R.N. London, 1901. 8vo 292 pp.

The author has collected in this volume the lectures delivered by him to the surgeons under instruction at the R.N. Hospital, Haslar. The work is divided into 3 parts, Part III. being devoted entirely to Meteorology. It is satisfactory to know that a knowledge of Meteorology is becoming necessary to Naval Medical Officers and to candidates for the Diploma in Public Health.

The author states that "the term climate is used to convey an impression as to the meteorological conditions existing in a country or place dependent upon *temperature* and *relative humidity.*" We do not agree to this restricted definition of the term "climate"; we consider that it embraces much more than temperature and relative humidity. The best definition is that given in Bartholomew's *Atlas of Meteorology*, viz. "Climate is the average condition of any region; these are temperature, moisture in all its forms (vapour, cloudiness, and precipitation), wind, and storms. Pressure may be included in so far as it affects the wind system."

The author is not familiar with the names of meteorologists or he would not have spelt the name of the President of the Royal Meteorological Society as Dine instead of Dines. No reference is made to the Jordan Sunshine Recorder, although an illustration is given of the Whipple-Casella Recorder. We do

not see the reason of giving an illustration of the Casella Mercurial Minimum thermometer when no illustrations of the maximum and minimum thermometers in almost universal use are given.

Knowledge. An Illustrated Magazine of Science, Literature, and Art. January—June 1901. 4to.

Contains the following papers :—"The Size of Ocean Waves" : by Vaughan Cornish (12 pp.).—"Gradual Change in our Climate": by A. B. MacDowall (1 p.).—"Rainbow Phenomena": by Paul A. Cobbold (1 p.).—"Exploring the Thunder-Cloud": by the Rev. John M. Bacon (3 pp.)—"Rainfall in South Africa": by Arthur H. Bell (1 p.).—"Sunset Phenomenon": by R. L. M'Donald and E. E. Markwick (1 p.).—"Sunspots and Terrestrial Temperature": by Percy Quensel and G. M'Kenzie Knight (1 p.).—"Antarctic Exploration": by Wm. Shackleton (4 pp.).—"On the Audibility of the Minute-Guns fired at Spithead on February 1": by Charles Davison (1 p.).—"Sunspots and Weather": by A. B. MacDowall (1 p.).—"On the Capricious Hearing of certain Sounds at Long Range": by Rev. J. M. Bacon (2 pp.).

Lehrbuch der Meteorologie. Von Dr. JULIUS HANN. Part III. 8vo. Leipzig, 1901.

In continuation of our Notice (pp. 163-164) we now come to Book III., "The Aqueous Vapour in the Atmosphere and the Effects resulting therefrom." Evaporation is briefly dismissed, owing mainly to the intrinsic difficulty in obtaining figures applicable to large surfaces of water from apparatus of a manageable size for observation. This is in great measure due to the circumstance that small vessels warm themselves much more than large ones. Dr. Hann then deals with hygrometric determinations in general and the merits of the different methods of attaining the end. As regards the vertical distribution of vapour, it is pointed out that Strachey was one of the first to show the untenability of the old theory of two separate atmospheres, the dry air, and the vapour, respectively. The balloon observations have proved that the reduction in the amount of vapour with height, takes place more rapidly in the free air than is shown by the observations at mountain stations. The estimated figures are :—

For mountain stations $C = 6{\cdot}5$ km.
For free atmosphere $C = 5{\cdot}0$ km.

The mean condition in the free atmosphere is found by multiplying this figure by the modulus of Briggs' logarithms, so that we have $5 \times 0{\cdot}4343 = 2{\cdot}17$ km. as the height of a vapour column which represents the moisture actually existing in the atmosphere under ordinary conditions of pressure and temperature.

We find then a notice of the distribution of humidity over the earth, the least being about 20 per cent in the Californian desert and in Central Asia at 1 p.m. in summer.

Dr. Hann next treats of the diurnal and annual march of vapour with an interesting diagram from Angot on the daily march of temperature and humidity in Senegambia, under the influence of the setting in of the sea-breeze. At Allahabad the humidity is 31 per cent in April, 82·5 per cent in August. At Batavia the figure throughout the year only varies from 78 to 87 per cent.

Then comes the great question of the condensation of vapour and the causes which bring that about. The principal of those is the ascent of the air, and this itself is most frequently due to mechanical obstacles, like mountain chains; then comes a notice of von Bezold's calculations (with diagrams) of the amount

of condensation which results from the mixture of masses of air of different hygrometric constitutions.

"The condensation of vapour on the earth and on objects thereon":—In this we have an account of all the varieties of hoar frost and silver thaw. It appears that the great developments of hoar frost at mountain stations are not crystalline, but frozen raindrops which arrange themselves by agglutination in the most various forms like the frost-feathers on a window-pane. This has been proved by Assmann. As to the condensation of vapour, we have first the refutation of the bubble theory, mainly by Dines' determination of the size of drops. Then we deal with Aitken's nuclei and discuss the various types of fog and mist. This brings us to clouds and the international classification of them.

The mode of generation of the various forms is dealt with at length, although our author admits that the explanation is not complete. Several instances of cloud formation over volcanoes are cited. This is followed by an account of the various results obtained all over the world as to cloud altitudes and velocities; the section ends with the distribution of cloudiness at the various hours and in various places, and this leads on to the registration of sunshine, and the circumstance is pointed out that at most stations the forenoon is clearer than the afternoon. As to distribution, it is remarkable that in some tropical regions the rainy season has the most clear sky, the heavens being quite obscured during the dry season.

Now come the subjects of rain and snow, and Dr. Hann admits that many points about these require further elucidation. He deals with the ideas as to the electrical agency which may cause the small particles of a cloud to coalesce and fall. As to the size of raindrops, Wiesner has shown that they cannot much exceed 45 grains. If larger drops fall even 8 inches, they break up in their descent. In the notice of the chemical composition of rain we do not see Dr. Angus Smith's announcement that nitrogen compounds in the rain increase in amount with distance from the west coast. Snow is very various as to its density, and it is remarkable that it is not possible to build snow-houses with the snow falling, *e.g.*, in New York, as it is so much damper than the dry Greenland snow. Lastly, we come to the measurements of rain and the question of its variation over the surface of the ground and with height above it. Dr. Hann points out that Heberden (1766) was the first to make observations on this point, and that W. S. Jevons first proved that the cause of the diminution with elevation was the wind. At the same time no law for the diminution is possible, inasmuch as it is nearly a purely local phenomenon.

The rain section closes with a very full and careful treatment of the whole question of the calculation of rain data, and the distribution of precipitation in the yearly period, as well as the attempts that have been made to discover a secular period for it. On this head the papers of Binnie and Symons are largely cited, and, of course, those of Brückner. Then comes the discussion of the diurnal period, and it comes out as an interesting fact that Paris in winter shows a maximum in the early morning, like Valencia, whereas in summer the maximum falls in the afternoon, as it does at Kew. The whole explanation of these differences will well repay perusal. Book III. winds up with an examination of the geographical distribution of rain, followed by an account of heavy rains in short periods, and their connection with thunderstorms.

Leitfaden der Wetterkunde. Von Dr. R. BORNSTEIN. Brunswick: Vieweg. pp. 181. Plates XVII.

Dr. Börnstein is Professor at the Agricultural Model School in Berlin, and he describes, on his title-page, his work as intended for general comprehension,

but we think that towards the end of the book he addresses himself much more *ad clerum* than *ad populum*.

On the whole, however, the work is very useful, though, naturally, its instances of phenomena are taken almost entirely from Germany, and do not exactly represent the weather of these islands. It leads off with the general statement that it is the Gulf Stream, pure and simple, to which the mild climate of these islands and of Western Norway is due, in oblivion of the fact that the Gulf Stream *as a current* is not traceable beyond the banks of Newfoundland, and that the statement ought to have been that it is the warm water of the Atlantic Ocean which produces all the effects so graphically described.

As regards night frosts, and their destructive effects on crops, he cites a remarkable statement of Neergard's to the effect that in Holstein when they fear frost at night they flood the fields, and let the water off again when the sun is up. It would appear to us that the fields must be very level, and we should fear that the ground would be left very wet. We do not see how such a plan could be adopted for the potato fields in Scilly, where a night's frost spoils the whole crop.

Under the head of "Temperature" we find an interesting summary of recent balloon results. On one simultaneous ascent in June 1898 in which four balloons took part, the diurnal range of temperature at ground level being taken as 100, the successive ranges were—at 700 metres, 50 ; 1100 metres, 33 ; 1400 metres, 25 ; 1600 metres, 20 ; 2000 metres, 14 ; 3000 metres, 5 ; above that level, hardly perceptible.

An interesting quotation from Ceyp in *Himmel und Erde* tells us that at Bushir, where the sultriness of the atmosphere is almost unbearable, it is during the hottest part of the day that walking is possible, for increase of temperature lowers the relative humidity.

At p. 36 we have a full treatment of the Föhn question, and it is pointed out that the first person to propose the explanation which attributes it to the ascent and descent of the air, caused by translation over a mountain chain, was given by Ebel in the Zürich Naturforscher Gesellschaft about 200 years ago, and subsequently by Espy in 1841, though the positive proof of its truth has been supplied by Wild and Hann.

Dr. Börnstein goes in decidedly for Helmholtz's cloud waves, and this portion of the work is well worth reading.

Under the head of "Twilight" we have, of course, the Krakatoa phenomena brought in, but more particularly von Bezold's discussion of the subject, with the subdivision of the illumination into the "dark segment," the first and second "bright segments," and the "Eastern" and "Western" twilight bows, there being two of the latter.

In dealing with the effect of pressure in lowering the freezing-point of water we find notice of an interesting experiment. If a wire is laid across a block of ice, and each end weighted, the wire will cut its way through the ice, but the ice will close up behind it by regelation, leaving no trace of the passage of the wire. The same action takes place in skating. The ice thaws under the pressure of the skate, but forms again as the skater passes on.

We find several instances cited of the effect of planting in augmenting rain, both from Germany and from India.

In speaking of the diurnal range of rain we have mention solely of continental falls, with a maximum in the afternoon, but no allusion to the early morning maximum, characteristic of the Atlantic coast of Ireland.

Dr. Börnstein goes into the general theory of tides, and shows how the atmospheric tide cannot appreciably affect the diurnal oscillation of the barometer. All this reasoning appears to us to have little to do with weather.

When our author comes to squalls and thunderstorms he is quite in his

element, for he is already known for important papers on the occasions of these phenomena.

In his notice of atmospheric electricity he goes on to speak of the ionisation of air, and quotes, *inter alia*, Mr. C. T. R. Wilson's experiments, but this, again, is rather above the comprehension of the ordinary public.

Van Bebber's storm tracks and weather types are discussed in very considerable detail.

The last chapter of the book gives a *résumé* of the actual state of the Weather Service in different countries. As regards these islands he never mentions Admiral FitzRoy in his account of the development of storm warnings! He also says that *The Times* produces daily the weather chart of the previous day, but he does not point out that it is the chart for 6 p.m. on the evening before issue, and not the ordinary 8 a.m. chart.

Among the plates there are several reproduced from the *International Cloud Atlas.*

Meteorologische Zeitschrift. Redigirt von Dr. J. HANN und Dr. G. HELLMANN. February—June 1901. 4to.

The principal articles are:—"Einige Bemerkungen über die Schwerekorrektionen der Barometerhöhen": von Prof. H. Mohn (4 pp.). Prof. Mohn has long been known as the advocate of the use of the boiling-point thermometer, instead of the barometer, as the former enables one to determine the correction for gravity. He shows that Broch's table for this correction in the *International Tables* is not quite correct, as is shown by Schiötz's pendulum observations in the course of 1900. Prof. Mohn gives instructions for the use of the hypsometer, showing how every observation must be repeated three times, the apparatus being most carefully and thoroughly cleaned out after each individual reading. Such a procedure shows that the hypsometer must not be placed in the hands of an inexperienced observer. The short paper concludes with specimen calculation of results.

"Platzregen und grosse tägliche Regenmengen": von A. Woeikof (5 pp.). Dr. Woeikof takes the three stations of Hong-Kong, Batavia, and Costa Rica, in order to see how the days of downpour exceeding 40 mm. (1·5 in.) per day are distributed. He also gives occasions on which 0·75 in. fell in a single hour at Costa Rica. These heavy falls are almost exclusively in the afternoon; at Batavia they are principally in the morning; and at Hong-Kong they are almost always in the morning. Dr. Woeikof gives also the figures of Batoum, the wettest place on the sea-coast in Europe, where the fall is 2483 mm. (90 ins.). At Batoum, days of heavy fall are much more frequent than at Batavia and Costa Rica, and rather more frequent than at Hong-Kong.

"Beiträge zur Hageltheorie": von Prof. Dr. Schreiber (13 pp.). This is an endeavour to explain mathematically the origin of hailstones, in answer to a criticism of Dr. Schreiber's by Dr. Trabert of Vienna. Dr. Schreiber quotes specially the very remarkable cloud and hailstorm mentioned in the *Quarterly Journal* of the Royal Meteorological Society, vol. xxii. p. 235.

Among the *Kleinere Mittheilungen* there are notices of two of the international balloon flights, of November 8, 1900, and January 10, 1901; and also a further discussion of the temperature results of the two balloons sent up from Vienna on November 8, the peculiar flights of which were noticed in the last number of the *Quarterly Journal.*

"Beiträge zur Gewitterkunde in Hohen Venn und der Eifel": von Dr. P. Polis (9 pp.). The active Director of the Observatory of Aix-la-Chapelle gives a discussion of the frequency of thunderstorms in the district lying to the south-east of that city. The Hohe Venn lies due south of it, and has a

minimum of thunderstorms. The maximum, with three times as many cases, lies on the north-east slope of the mountain. Dr. Polis shows that the investigations over the whole of Germany lead to a somewhat similar conclusion. The storms are further discussed as to their annual and diurnal frequency.

"Versuch einer Klassifikation der Klimate, Vorzugsweise nach ihren Beziehungen zur Pflanzenwelt": von Dr. W. Koppen (15 pp.). We have already noticed this work, of which this is a condensed abstract.

"Ueber die Halophänomene": von Dr. J. B. Messerschmitt (11 pp.). This is a reprint from the *Annalen der Hydrographie.* We find in it the recognition of the old German nomenclature of small and large *Höfe*, the small being *coronæ*, the large, *halos.* The author seeks to establish a periodicity in the occurrence of halos, solar and lunar, corresponding to that of auroræ and related to that of sunspots.

"Cannonading the Clouds." Dr. Pernter quotes a report by Signor Stabiliur, Inspector-General of the Hail Insurance Company of Milan, which says that in spite of regular and continuous firing no diminution whatever in the average number of cases of hail damage was traceable for the year 1900.

"Die Entwickelung der Meteorologischen Beobachtungen bis zum Ende des xvii. Jahrhunderts": von G. Hellmann (13 pp.). Dr. Hellmann, who has earned the thanks of all meteorologists by his reprints of rare old works on meteorology and magnetism, has now given a summary of all that he can collect of old meteorological literature. The earliest meteorological observations come from Palestine, and date back to the first or second century of our era. They referred exclusively to rain, "The former and the latter rains," and the earliest figures agree very well with the modern records. The early rains were given as about 21 ins., while Mr. Chaplain finds 19·7 ins. The earliest printed journal is that of William Merle, which was reproduced by Mr. Symons. It dates from 1337. The whole paper affords very interesting reading. It concludes with a table of the dates of the earliest records traceable. The earliest publication of observations was 1546, in Nuremberg. The first Arctic observations were those of Barentz in 1596. The first instrumental observations were from Claremont-Ferrand, 1649; and the first marine meteorological log was that of Columbus, 1492-93.

"Cirrus-Studien": von Dr. H. J. Klein (15 pp.). The author began to observe cirrus clouds more than 40 years ago. They were then known under Humboldt's name of "polar bands." The present paper gives a summary of the conclusions at which Dr. Klein has arrived, and which, on the whole, agree with the rules for interpretation of cirrus observations which are now generally accepted.

"Neunte Allgemeine Versammlung der Deutschen Meteorologischen Gesellschaft zu Stuttgart am 1-3 April 1901" (18 pp.). This is a summary of the Proceedings at the Meeting of the German Meteorological Society. The subject which excited most attention was that of the supposed influence of cannon-firing in dispersing thunder-clouds. Experiments were carried out, but the result was *nil.*

"Einige Ergebnisse der Temperaturbeobachtungen auf dem Strassburger Münsterthurm": von J. Hann (6 pp.). Dr. Hann has discussed five years' observations at the top of the Minster Tower (about 446 ft.). The results are similar to those from the Eiffel Tower, and they show that the influence of the slight connection with the earth afforded by the point of the tower is enough to modify the daily extremes when compared with those taken in free air.

"Ueber Niederschlagsschwankungen in den Flussgebieten der Wolga, des Dnjepr und des Don während der Periode 1861-98": von E. Heintz (7 pp.). This investigation was originally started by the late Gen. A. von Tillo. Dr. Heintz gives tables of rainfall for the several rivers for the whole period, but

concludes by showing that no decided progress of increase or decrease in discharge is discernible.

"Die Luftdruckverhältnisse und die Windbewegungen im Fernen Osten": von P. Bergholz (9 pp.). This is a summary of the contents of the 7th Annual Report of the Shanghai Meteorological Society, which is a discussion by Père Aloys Froc, on "The Atmosphere in the Far East during the six cold months: its normal state, its perturbations." This report is illustrated by six maps, taking in practically Western Asia from Cape Comorin and the North Pacific, as they show the Aleutian peninsula in Alaska. As the original work is in English, and in the Society's library, we must refer those interested in the subject to it. Dr. Bergholz writes for the German public. He draws special attention to the study of the winter storms.

"Ueber Wirbelbewegungen in vulkanischen Rauchwolken": von K. Mack (7 pp.). This is an interesting study of the movements of smoke over volcanoes. The author points out that if any liquid or gas is poured out of a vent, such as smoke from a chimney, under the influence of a pressure exerted from below, definite vortex rings will be formed. If the pressure continues the jet will take the mushroom form, the stalk will grow in length to a considerable extent. The same thing may be noticed if a coloured liquid is forced upwards into a colourless liquid at rest. The phenomenon can easily be observed by watching smoke coming out of the funnel of a steamer, distinct rings can be recognised. Dr. Mack gives accounts of his own observations at Vesuvius, with a woodcut showing separate rings rising laterally from the main smoke column. The woodcut is from a photograph. In general, these rings have their axes horizontal, but sometimes vertical.

"Die österreichischen Ballonfahrten beim Luftdruck-Maximum am 10 Januar 1901": von J. Valentin (13 pp.). This is a concise account of the balloon ascents during an anticyclone. It commences with a discussion of the records from unmanned balloons (*ballons-sondes*). The actual ascents took place, one at the centre of the anticyclone near Přzemyśl in Galicia, reaching 3054 metres (10,020 ft.), and the descent at the euphonious locality of Hucisko nienadówskie, about twenty-three miles off; the other at Vienna, reaching only 2740 metres (8900 ft.). An unmanned balloon from Vienna reached 9640 metres (31,628 ft.), and descended in two hours at Gmünd. It appears from the calculations that the anticyclone had only a vertical altitude of 5000 metres (16,405 ft.), and that the unmanned balloon ascended into the depression which lay above the anticyclone. The whole paper is of extreme interest.

"Aeltere Versuche zum Schutze gegen Hagelschläge": von O. A. von Obermayer (4 pp.). This is a paper on gun-firing against hail.

Mysore Meteorological Memoirs, No. I. Folio. 100 pp. and 14 pl. Bangalore, 1901. Published under the authority of the Mysore Government.

The Introduction to the volume contains an account of the Meteorological Observatory, Bangalore, and a description of the recording instruments in use.

The Meteorological Observatory, Bangalore, was built during 1893-94, by the Public Works Department of the Mysore Government, from the plans (slightly modified) of the Government of India Observatory at Alipore, Calcutta. All the instruments were placed *in situ* during the latter months of 1894, and all the records and observations have been (practically) uninterrupted since January 1, 1895. The records dealt with in this volume are the hourly readings from the Barograph, Thermograph, Pluviograph, Anemograph, and the Campbell-Stokes Sunshine Recorder, for the four years 1895 to 1898.

Researches on the Past and Present History of the Earth's Atmosphere, including the Latest Discoveries and their Practical Application. By Dr. THOMAS LAMB PHIPSON. London. 1901. 8vo. 214 pp.

This work is to a great extent the result of the author's own observations, which have spread over a considerable number of years. It "contains the results of the latest discoveries connected with the vast aërial ocean which surrounds the earth, the physical and chemical properties of the air, its geological history as far as we can trace it into the remotest ages of the past, and the useful deductions that can be drawn from all these facts." So far as meteorology is concerned, the author has apparently not kept pace with the times, as he has not included "the latest discoveries" in this science, for hardly any reference is made to the advancement since the time of FitzRoy.

Results of Meteorological Observations made at the Radcliffe Observatory, Oxford, in the eight years 1892-1899. Edited by ARTHUR A. RAMBAUT, M.A., F.R.S., Radcliffe Observer. Vol. XLVIII. 8vo. 1901. 245 pp.

Till the year 1891 a volume of results had been published annually. Owing to the death of Mr. E. J. Stone, the former Radcliffe Observer, and the changes consequent upon the appointment of his successor, no volume has been published till the present one, which contains the results for the eight years 1892-99. The observations have been carried out on the same lines as formerly, except with the addition of the readings of the temperature of the earth at various depths below the surface by means of five platinum-resistance thermometers. A description of the apparatus, the mode of reduction of the observations, and a notice of some of the results to be derived from the observations of the year 1899 are given in the introduction.

Symons's Meteorological Magazine. Edited by HUGH ROBERT MILL, D.Sc., LL.D. April—September 1901. 8vo.

The principal articles are:—"The Blood-Rain Plant at Camden Square" (2 pp.). The water in the large evaporation tank having assumed a rich deep crimson colour, a microscopical examination was made of the same, when it was found that the colour was due to the presence of swarms of a minute moving water-plant, the *Sphaerella pluvialis* ("the blood-plant of rain").—"Climate of Pemba" (2 pp.). This is a note by Mr. T. P. Newman, contributing a table of results of observations for 1899 and 1900 at Banani, Island of Pemba, on the east coast of Africa.—"Demchinsky's Weather Forecasts for April" (4 pp.).—"On the Occurrence of Waves of Exceptional Size": by V. Cornish (2 pp.).—"International Investigation of the Sea and Air" (3 pp.). This is an account of the proceedings of the International Conference held at Christiania from May 6 to 11, 1901.—"Proposed Observations on Dew-Ponds." This subject has already been dealt with in a previous number of the *Quarterly Journal* (see *ante*, p. 115).—"Mean Temperature (Southern Counties), 1885-1900": by A. F. Parbury (2 pp.).—"The Norwegian Rainfall Service": by Prof. H. Mohn (2 pp.).—"Low Relative Humidities in May, 1901": by R. H. Barnes (1 p.).—"On a Fallacy as to the Diurnal Barometer Wave": by W. H. Dines (3 pp.).—"Unprecedented Heat in New York" (1 p.).—"The London Thunderstorm of July 25" (3 pp.). During this storm the total rainfall at Camden Square was 2·85 ins., of which 2·66 fell in an hour and a half.—"Meteorology on the British Antarctic Expedition" (3 pp.).—"On Thunderstorms": by R. H. Curtis (2 pp.). "A Hot Day in North-west Lancashire": by S. Wilson (2 pp.). On July 20 the temperature rose to 89°.

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THE END OF VOLUME XXVII.

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MEZZANINI